A DISCRIMINANT MODEL FOR CLASSIFYING CONTRACTOR PERFORMANCE ON PUBLIC WORKS PROJECTS

Chee. H. Wong Dip., MSc.

A thesis submitted in partial fulfilment of the requirements of The University of Wolverhampton for the Degree of Doctor of Philosophy

November 2001

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Signature ....

Date ......17th Dec. 2001..........

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ABSTRACT

Contractor selection practices in the UK construction industry have long been criticised and presently a divergent range of methods and preferences exists. Albeit, many of the practices adopted comply with *good guidance practices* and *recommendations* from construction reports and commentators. This research focused on UK construction clients' contractor selection *preferences* i.e. prequalification criteria (PC) and project-specific criteria (PSC). The main aim was to develop a contractor classification framework to assist construction clients' decision-making during tender evaluation. Investigating client selection preferences and behaviours are the main focus of this research. However, attention was also given to the contractors' views upon selection, from prequalification to invitation-to-tender.

Factors affecting clients' non-use of standard prequalification practices were found to be a perceived: lack of *flexibility* and *tolerance* to clients' specific needs; and a *long term confidence* with 'in-house' selection practices. With regard to the use of PC and PSC, there appears to be much concordance among clients and contractors, but *levels of importance assigned* by public clients and clients' representatives were found to be significantly different to some extent in building and civil engineering works.

Based on data from 68 small to medium size UK minor works (below £50 million), a contractor classification model (i.e. Z_2 model) was developed. Multivariate discriminant analysis is used to classify contractors' past performance into good and poor groups. The classification model is made up of 5 variables: (i) contractors' plant and equipment resources; (ii) past performance in time on similar projects; (iii) past performance in cost of similar projects; (iv) reputation and image; and (v) relationship with local authority. The developed model has a 90% accuracy in classifying contractors into 'good' and 'poor' groups and a 70% accuracy when tested against independent data.

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Dedicated to my grandmother and my parents

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List of Abbreviations

ANOVA	Analysis of Variance
APM	Association of Project Management
ASCE	American Society of Civil Engineers
CIB	Construction Industry Board
CIC	Construction Industry Council
CIOB	Chartered Institute of Building
CIRIA	Construction Industry Research and Information Association
CMIS	Contractor Management Information System
ConReg	Register of Consultants
DETR	Department of the Environment, Transport and the Regions
DoE	Department of the Environment
DTI	Department of Trade and Industry
EU	European Union
GLM	General Linear Model
ICE	Institute of Civil Engineers
IOB	Institute of Building
LA	Local Authority
LIA	Levels of Importance Assigned
MANOVA	Multivariate Analysis of Variance
MDA	Multivariate Discriminant Analysis
NEDO	National Economic Development Organisation
NFHA	National Federation of Housing Associations
NJCC	National Joint Consultative Committee for Building
NQS	National Qualification System
OJEC	Official Journal of the European Communities
PC	Prequalification Criteria
PFI	Private Finance Initiative
PSC	Project-specific Criteria
RIBA	Royal Institute of British Architects
RICS	Royal Institution of Chartered Surveyors
SPSS	Statistical Package for Social Science
SRCC	Spearman Rank Correlation Coefficient

Definitions:

Client	An individual or organisation who commissions a building project (Bryant et al., 1969), and pays for the design and construction of the building (British Property Federation, 1983).
Classification	An independent procedure to classify future observation into one of two or more groups.
Contractor	An individual / organisations who are contractually employed by construction clients / owners to execute a construction project(s).
Correlation	An association between two varaibles where the increments / decrement in one variable occurs together with increments / decrement in others (Cohen and Holliday, 1996:p83-84).
Correlation Coefficient	An index of the degree reflecting the strength and the direction of association between the variables and the degree to which one variable can be predicted from the other (Nachmias and Nachimias, 1996;p400).
Covariance	The measure of two variables and how much they vary together (Klecka, 1980:p65).
Discriminant Analysis	The analysis that combines the group characteristics in a way that will allow one to identify the groups which a case most closely resembles (Klecka, 1980:p9).
Multicollinearity	Inter-correlationship among the variables.
Prequalification	A process of determining a candidate's competence or ability to meet the specific requirements for a task during contractor pre-selection stage (Russell *et al.*, 1992).
Prequalification Criteria	Criteria applied during the prequalification process for compiling a list of suitable contractors / organisations prior to tender-invitation.
Client's Representative	Refers to an individual / organisation who own and / or represent the development of projects on behalf of public and / or private clients.
Project-specific Criteria	Criteria applied during tender evaluation to prequalified contractors who have submitted their tender for a specific / proposed project.
Public Client	Refers to an individual / organisations who own and / or represent the development of public sector construction projects.
Tender Evaluation	A process of determining a tenderer's competence or ability to meet the specific requirements for a task prior to contract award.
Type I error	Rejecting the null hypothesis when it is in fact true (Weiss, 1995)

Type II error	Not rejecting the null hypothesis when it is in fact false (Weiss, 1995)

CHAPTER 1

INTRODUCTION

1.0 BACKGROUND TO THE RESEARCH

Since the 1970s construction industry commentators (e.g. Hunt *et al.*, 1966; Helmer and Taylor, 1977), practitioners (e.g. Moore, 1985a;1985b; CIC, 1993; CIDA, 1995) and researchers (e.g. Merna and Smith, 1990; Russell *et al.*, 1992; Holt 1995) have been investigating and proffering solutions to the problem of selecting the most 'appropriate' contractor. In the context of this thesis the term 'contractor' refers to the main contractor contractually employed by the construction client[1] / owners to physically construct the designed building.

The contractor selection problem is normally one of identifying a contractor who can undertake the client's project, and take it to satisfactory conclusion. That is, to meet the client's time, cost and quality expectations (Holt, 1995). Earlier investigations into the subject have attempted to redress existing weaknesses in the contractor selection process (i.e. 'lowest-prices' selection preference), and offer rationalised alternative(s) to present practice (e.g. Hunt *et al.*, 1966; Lewis, 1981; Hardy *et al.*, 1981; Martinelli, 1986). A variety of qualitative and / or quantitative selection methods have evolved as a result of such attention (e.g. Russell and Skibniewski, 1992a;1992b; Ng and Skitmore, 1995). Consequently, the construction industry has witnessed the emergence of a variety of contractor selection methods, and more

[1] The 'client' refers to public client and clients representative; 'public clients' include Local Authorities, Housing Associations, or other public sector construction projects owners; and 'clients representative' are those responsible for the development of projects in the private sector and / or representative of the public clients.

updated and objective contractor selection approaches (e.g. Russell and Jaselskis, 1992a;1992c; Herbsman and Ellis, 1995; Holt, 1998a). Generally, the clients who have embraced these 'scientific' selection procedures have tended to favour a quantitative and multi-criteria selection approach.

Despite these advances, the contractor selection 'problem' continues to generate tremendous interest among the construction management research community (e.g. Holt, 1995; Kumaraswamy, 1996; Hatush and Skitmore, 1997a; Ng and Skitmore, 1995). New findings pertaining to contractor prequalification / evaluation, and modelling techniques for predicting contractors' performance are constantly confirming that the subject area still justifies investigation (e.g. Abidali and Harris, 1995; Russell and Skibniewski, 1992a;1992b; Holt, 1995; Tam and Harris, 1996; Ng *et al*, 1999; Wong *et al*, 1999). This situation reflects the importance of this client decision task, and the need for judicious contractor selection (Holt, 1995; Jennings and Holt, 1998; Wong *et al*, 2000a;2001a).

Both the industrial and academic worlds have expanded the study of contractor selection (e.g. CIC, 1993; CIDA, 1995; Holt, 1995; CIB, 1997; Hatush, 1996). The fundamental rationale underpinning this effort is to recognise unscrupulous contractors at an early stage (i.e. to ensure that only the 'right' contractors are invited to tender), to deter poor project performance, and in the extreme, avoid project (contractor) failures. In other words, an accurate objective selection approach, able to provide an early 'warning' sign to clients (before the final selection decision) would be optimal. Another ongoing feature of the construction industry is an increased use of objective (via-a-vis subjective) approaches in the selection process (Holt, 1998a).

As these more recent approaches have emerged, there has been a trend away from a 'lowest-price wins' principle, to a multi-criteria selection approach (Jennings and Holt, 1998; Wong *et al.*, 2000a:2001a).

1.1 PREVIOUS STUDIES

The early 1960s, witnessed a growing interest in the contractor selection problem as evidenced by work aimed at the construction sector of several major countries (e.g. Hunt *et al.*, 1966; Banwell, 1964; Higgin and Jessop, 1965; Martinelli, 1986; Moselhi and Martinelli, 1990). Significant investigations into contractor selection and evaluation methods have more recently expanded. Some examples of this growing interest are:

i. Discounted Cash Flow Techniques (Hardy *et al.*, 1981).

ii. The application of Multidimensional Utility Theory (Diekman, 1983; Moselhi and Martinelli, 1990).

iii. Fuzzy Set Theory (Nguyen, 1985; Juang *et al.*, 1987).

iv. Multi-parameters Evaluation Bidding System (Herbsman and Ellis, 1992).

v. Qualifier-1 and Qualifier-2 for Contractor Prequalification (Russell and Skibniewski, 1990a;1990b).

vi. Decision Support System (Ng and Skitmore, 1995).

vii. Highlight Optimum Legitimate Tender (HOLT) Selection Techniques (Holt 1995).

viii. Programme Evaluation and Review Technique (PERT) Approach (Hatush and Skitmore, 1997a).

ix. Decision Support Systems for contractor prequalification- an artificial neural network approach (Lam *et al.,* 2001).

These investigations sought to determine solutions for specific national economic and socio-economic characteristics, and gave rise to a large variety of contractor selection practices. For example, in the US, there has been extensive work to improve the contractor prequalification process (e.g. Harp, 1971; Russell and Skibsniewki, 1989; Russell *et al.*, 1992). Whilst in the UK, the construction industry has witnessed development of several alternative selection processes and objective evaluation methods (e.g. Moore, 1986a;1986b; CIC, 1993; Holt *et al.*, 1995a; Ng and Skitmore, 1995; Holt, 1998a; CIRIA, 1998).

Notwithstanding these developments, the need for further revision of present selection practices remains (i.e. for continuous improvement). The majority of current practices (in the UK construction industry) are subjective; they rely on prequalification and tender sum during final selection; and there is no universally accepted approach towards the contractor selection process (Merna and Smith, 1990; Holt *et al.*, 1995a). Furthermore, the construction industry, especially with respect to procurement is dynamic, and no one particular selection method has yet evolved able to cope with all different selection scenarios, which themselves, change constantly over time.

In addition to the earlier mentioned contractor selection and evaluation methods, research into this subject domain also includes:

i. Helmer and Taylor (1977): evaluation of contractors' management when selecting a contractor in America.

ii. Merna and Smith (1990): contractor selection for public civil engineering works in the UK.

iii. Herbsman and Ellis (1992): evaluation and selection of contractors using a multi-parameters bidding system for American highway construction projects.

iv. Liston (1994): contractor prequalification criteria for civil engineering works in Australia.

v. Potter and Sanvido (1994): investigation of design and build prequalification systems for public works.

vi. Ng and Skitmore (1995): decision support systems for contractor prequalification.

vii. Tam and Harris (1996): identification of factors that influence contractor performance and development of a model for predicting contractor performance (in the Hong Kong construction industry).

viii. CIRIA (1998): who placed emphasis on achieving value in the selection of contractors.

ix. Palaneeswaran and Kumaraswamy (2000): the benchmarking contractor selection practices conceptual model for public sector works.

These works have also strengthened the *multi-criteria* approach to contractor selection and placed greater emphasis on the use of alternative selection methods. For instance the desire (need) to evaluate the strengths and weaknesses of financial and non-financial features of contractors; as a means of predicting their likely performance. The need for such research has emanated due to increasing construction project complexity and uncertainty, increasing clients' expectations and demands, increased competition and higher performance requirements (i.e. stringent financial arrangements and shorter construction times).

The present diversity of selection methods has also cultivated a wide variety of 'in-house' practices and practitioner / company individual selection preferences (Wong *et al.*, 1999). Such divergence has inexorably contributed towards the inefficiency of the construction process, this being particularly so in the public sector, as criticised by Latham (1994). It is costly and time-consuming to use 'unstandardised' and diversified practices (i.e. numerous forms of prequalification questionnaires and contractor standing / tender lists).

Standardisation was highly recommended by Latham (1994), who emphasised that contractor selection should exhibit a more disciplined approach. This in itself calls for the use of 'standard' contractor lists and efficient methods of contractor prequalification inquiry during early selection stages. The need for standardisation and streamlining of practice in striving for greater efficiency and reduced costs has also more recently been reiterated by Egan (1998).

1.2 THE PRESENT RESEARCH

Investigation into contractors' attributes for given **types of projects** and for **different types of clients** has received much less attention, particularly, in the **levels of importance assigned (LIA)** to contractor selection criteria. The present research has identified selection criteria and their LIA, both for the *prequalification* and *tenderer evaluation* stages of contractor procurement. Whilst in the tender evaluation, conflicting views regarding whether the selection process should be an objective one, or whether lowest bid should 'rule-the-day' also investigated.

Current methods of contractor selection are generally ad-hoc, bespoke and lack a universally accepted approach. A majority of the contractor selection methods are based mainly on subjective selection regardless of the degree of 'risk' that might impact on contractor project performance (Merna and Smith, 1990; Harp, 1990; Holt *et al.*, 1995a). On the contrary, it has been recognised that some 'academic' (research-based) selection methods for evaluating a contractors' potential are too complicated and 'inappropriate' for construction clients (e.g. Nguyen, 1985; Juang *et al*, 1987; Holt, 1998a; Lam *et al.*, 2000). Hence, there is a need for a method that can accurately 'identify' a 'poor' contractor, if such identification (methodology) is economically worthwhile. This presents a knowledge gap filled by this research via the analysis of construction clients' selection preferences that impact on the selection of a 'good' contractor. Therefore, it is the aim of this research to develop a model that links clients' selection preferences and contractor performance to help reduce client's selection burden, and in turn avoid the likelihood of project failure(s) to which the client may be exposed when awarding a contract to a 'poor' contractor(s).

1.3 RESEARCH AIM AND OBJECTIVES

The aim of this research is to: **develop a model that can classify contractor's performance into 'good' and 'poor' groups, to ease clients' burden during the contractor selection process.** This classification model will also benefit contractors, by eliminating the 'poor' (cowboy) contractor and thus creating 'fair' competition among 'good' contractors.

In order to achieve the research aim, the following objectives were established, and duly satisfied, as the research was implemented:

i. to investigate current UK construction clients' selection preferences with respect to contractor attributes and 'lowest-price wins' practices;
ii. to study the use of contractor lists, contractor selection criteria and their LIA in current contractor selection methods;
iii. to perform quantitative analyses on current contractor selection criteria preferences (i.e. PC and PSC), based on data gained from survey of UK clients;
iv. to incorporate the above findings into (quantitative) case studies for developing contractor classification models using discriminant analysis; and
v. to ultimately utilise findings from the research, to make suggestions for streamlining present-day selection practices, thereby contributing to improvement of the selection process and helping to reduce the burden of selection on construction clients i.e. through the use of the proposed contractor classification model.

Other objectives of this research were to investigate current UK construction client's contractor prequalification processes and perceptions regarding contractor selection criteria for given selection scenarios. That is, to study clients' perceptions on LIA for each selection criteria (i.e. interrelationships, association and divergence) in building and civil engineering works respectively.

1.4 THE BENEFITS OF THE RESEARCH

The principal benefits of such a contractor classification model would be:

i. to identify and classify contractors' performance ('good' or 'poor');

ii. resulting from (i) the reduced risk of project failure, hence making construction projects less risky;

iii. to prevent 'suspicious' (e.g. cowboy) contractors from entering into a contract;

iv. to prevent the possibility of losing a 'good' contractor; and

v. ultimately to reduce tendering costs.

Therefore, the issues reported in this thesis are beneficial not only to construction clients, but to the construction industry as a whole.

1.5 RESEARCH METHODOLOGY

Over the past few decades construction practitioners and researchers have attempted to redress the importance of contractor selection processes in **prequalification** and **tender evaluation** stages (e.g. Hunt *et al.*, 1966; Russell and Skibniewski, 1992a;1992b Latham, 1994, Holt *et al.*, 1995a). For instance, Hatush and Skitmore (1997a) and Holt *et al.*, (1995a) reported the extensive use of contractor *prequalification* and *tender evaluation* exercises in UK contractor selection practices. Moreover, there has emerged a trend away from the traditional 'lowest-price wins' selection preference (RICS, 1997; Wong *et al.*, 2001b). The above not only underlines the importance of contractor selection in *prequalification* and *tender evaluation* processes, but also the potential scope for future research.

Therefore, the present research focused on the 'two stage' selection process. That is, investigation of appointment of contractor during contractor *prequalification* and *tender evaluation.* The developed model could be equally applied to various procurement scenarios including: design and build, partnering and more traditional procurements routes during tender evaluation.

The research was initiated with a detailed and comprehensive literature study. The aim of this study was to discover previous and present-day clients' selection methods. This also identified the most 'influential' contractors' attributes. That is, **prequalification criteria**[2] **(PC)** and tender evaluation criteria (or more specifically **project-specific criteria**[3] **[PSC]**) that commentators considered most prudent during contractor prequalification and evaluation of tenderers. Here, *prequalification* refers to the 'screening' of contractors prior to invitation to tender (to be fully elucidated in chapters 3, 4 and 5). *Evaluation* of tenders (or more correctly, tenderers) refers to assessment of those prequalified contractors actually invited to tender for work (Chapters 5 and 6). The investigation of prequalification and tender evaluation was considered both from the point of view of contractors and clients. This was to enable the opinions of both parties to be compared and contrasted in regard to the contractor selection process. Further, this cross-verification enables better understanding and more valid results to be produced, whilst also revealing similarities and differences (Berkowitz, 1996:p33-51; Sommer and Sommer, 1991:p198-199). Hence, the

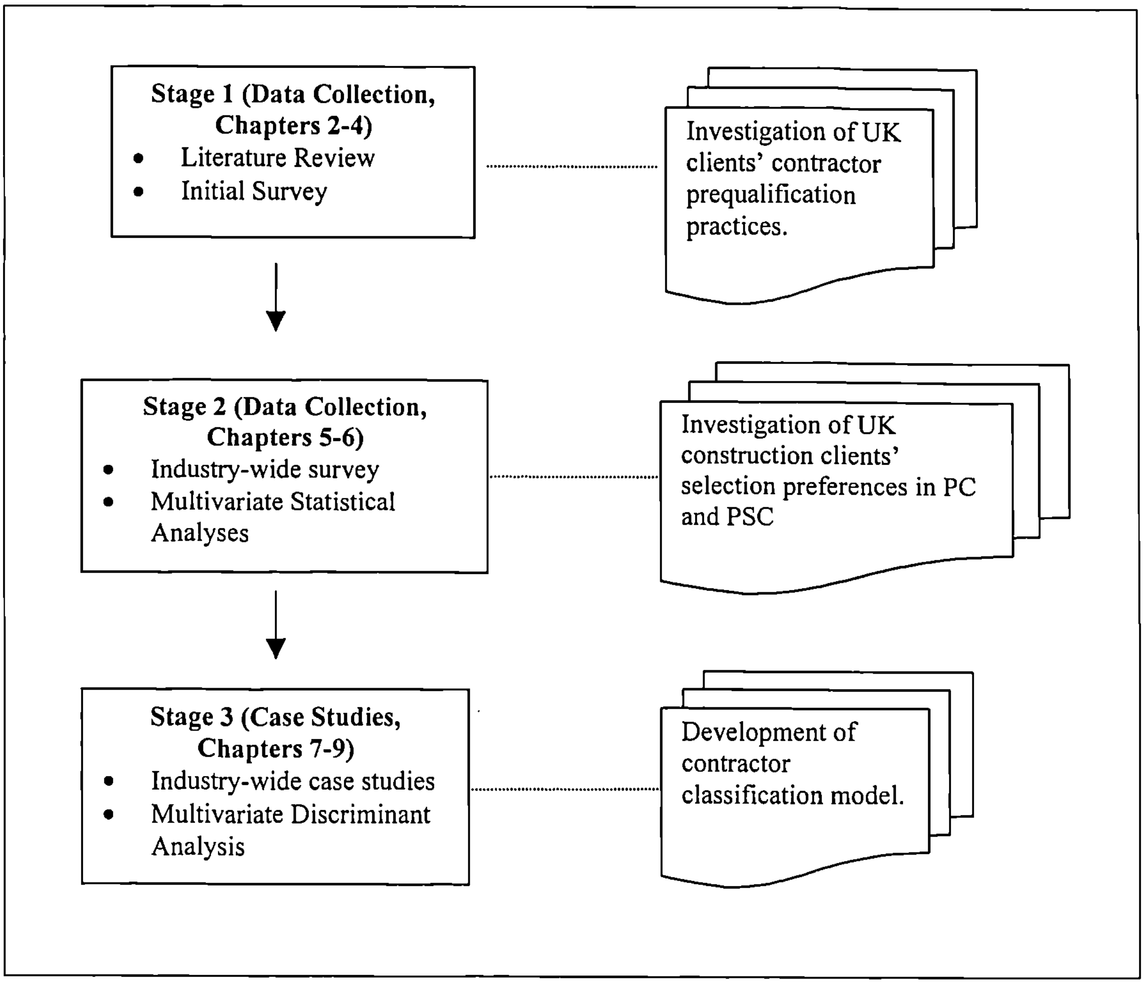
[2] Criteria applied during the prequalification process for compiling a list of suitable contractors / organisations prior to tender-invitation.

[3] Criteria applied during tender evaluation to prequalified contractors who have submitted their tender for a specific / proposed project.

research embraces comparative-judgements / opinions of both construction clients and contractors in regard to contractor selection.

The research methodology involved three different stages (Figure 1.1). First, the conduct of a literature review and initial survey of clients, consultants and contractors. This was followed by a second industry-wide survey of clients' selection preferences and finally the implementation of a case-study investigation.

Figure 1. 1: Flow Diagram of the Research Methodology



1.5.1 Literature Review

The literature review discusses the diverse practices of current contractor selection methods. It also confirms the inherent weaknesses of 'in-house' and 'standard' contractor selection methods for both building and civil engineering works. Attention is focused on PC and PSC and their levels of importance assigned during prequalification and tender evaluation (Chapter 3).

1.5.2 Initial Survey

Following the literature review, an initial survey of UK construction clients, consultants and contractors was conducted. The purpose of the survey was to **justify** the earlier literature findings (or otherwise); and through subsequent analysis and cross-comparison, consolidate the knowledge of current selection preferences and methods. The initial survey investigated the use of contractor lists (i.e. extent of usage, opinions thereto, and why) during the prequalification process (Chapter 4).

1.5.3 Second Industry-Wide Survey

Following the initial survey, the next step was to utilise early findings for developing a set of PC and PSC (Chapters 5 and 6). These criteria were prioritised, for use in different selection scenarios (i.e. building and civil engineering works and public / clients representatives). Investigation of clients' opinion regarding *levels of importance assigned* to these selection criteria was accomplished via a second (main) industry-wide survey of clients' and contractors and subsequently analysed using multivariate statistical techniques.

1.5.4 Case Studies

A case study survey-based method was chosen for developing a contractor classification framework (Chapters 7, 8 and 9). The empirical data (from the case studies) were used for developing contractor classification model(s) by means of the Multivariate Discriminant Analysis (MDA) technique. This technique groups clients' tender evaluation preferences (i.e. PSC and their LIA) used in tender evaluation into a discriminant model via worked samples (case studies). The derived discriminant function is subsequently able to yield overall classification results and discriminant factors that are able to reliably classify contractor performance.

1.5.5 Research Design and Survey Method

Bailey (1987:38) highlighted two different types of social research methodologies i.e. *exploratory* (descriptive) *studies* and *explanatory studies*. Exploratory studies, as embraced in this research, aim to learn more about a certain phenomena. This involved identifying current selection preferences of construction clients and the levels of importance assigned when selecting a 'good' contractor. However, explanatory studies go beyond the above and seek to explain a phenomenon by specifying 'why' and / or 'how' it happened. For example it involved explaining 'why' and 'how' clients' selection preferences impact on contractor performance.

The research concentrated on clients' contractor selection preferences and their potential effect on contractor performance. Such observation was limited by the resources (i.e. time, finance, etc.) available in PhD research. The exploratory studies therefore sought to help understand the phenomena (i.e. 'What' are the current contractor selection preferences) and to derive a solution for advancing the contractor selection issue (i.e. to propose a contractor classification framework). Hence exploratory studies provide a useful starting point to help develop theories and hypotheses in this research and recommendations for future studies (Chapters 9 and 10). A detailed account of the main research methodology is described in Section 4.3, Chapter 4.

1.6 ACHIEVEMENTS

During the time of writing this thesis, seven research papers have been accepted for publication and three are under review (Chapter 10). In addition, funding for further developing this research has been secured from the Royal Institution of Chartered Surveyors, under its Education Research Trust programme.

1.7 ORGANISATION OF THE THESIS

The thesis consists of ten chapters. Figure 1.2 provides a flow diagram showing the organisation and interrelationships of the research phases introduced above. The chapters are organised as follows:

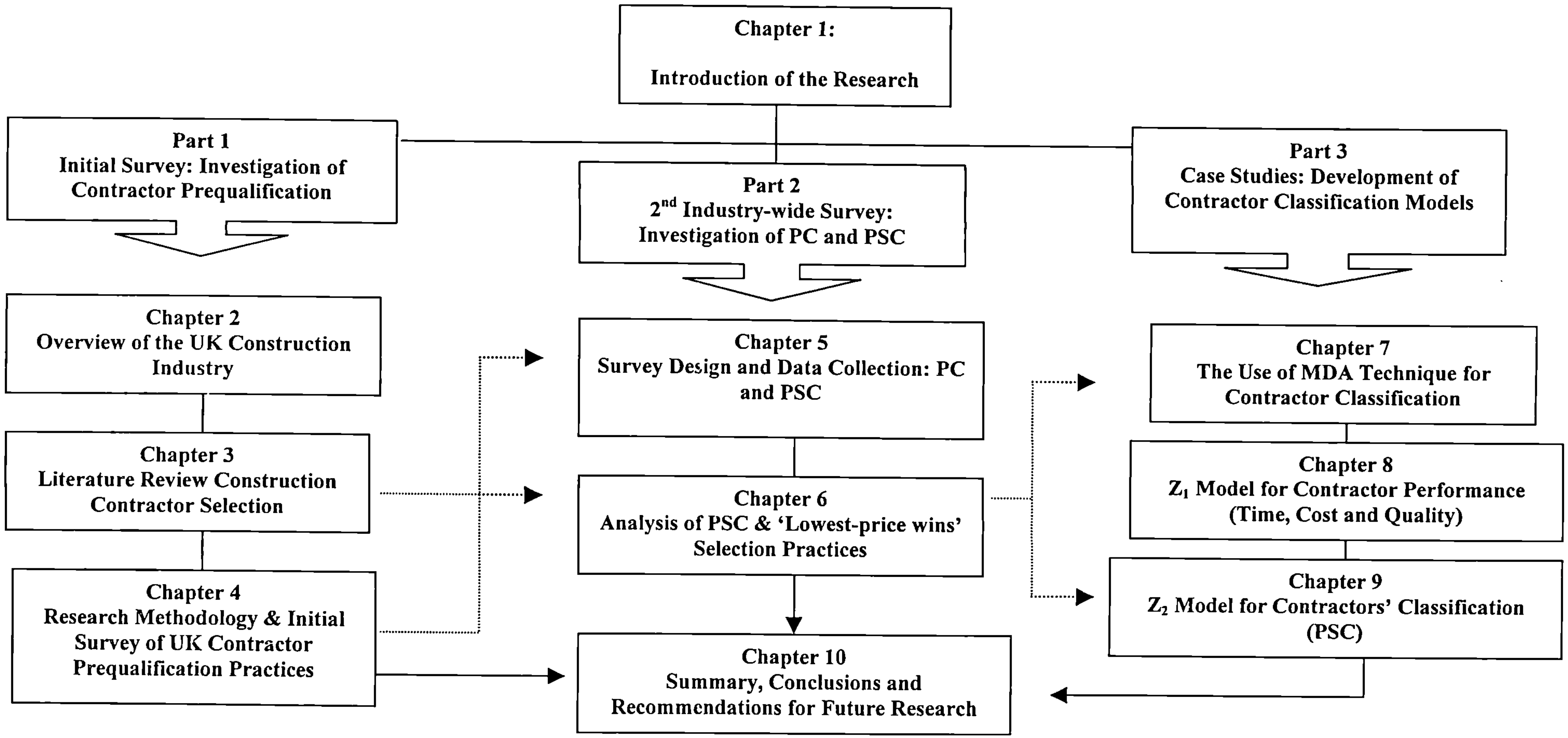
Chapter 1: Introduction

This is a general introduction to the research theme and the nature of the problem investigated. Chapter 1 discusses the aim and objectives of the research. It also sets the scene for the research and outlines the methodology employed.

Chapter 2: Overview of the UK Construction Industry

The second chapter presents an overview of the UK construction industry and its problematical aspects. Particular consideration is given to:

Figure 1. 2: Flow Diagram of the Thesis Organisation



i. procurement routes and contractual arrangements;

ii. traditional selection processes and principles;

iii. review of selection methodologies, and

iv. the problems caused by inappropriate contracting methods (in the context of contractor selection issues) including a retrospective comparison over the last three decades.

Chapter 3: Literature Review of Construction Contractor Selection

Following a general overview of UK construction industry performance and tendering practices in Chapter 2, Chapter 3 reviews contractor selection practices used in the UK construction industry. Attention is focused on PC and PSC. *Prequalification criteria* represent a set of contractor selection criteria (i.e. contractors' attributes) used during the prequalification stage prior to the compilation of tender lists whilst *tender evaluation criteria* are based on *project-specific criteria* (PSC). These are typically project-specific and more particular to clients' preferences and their projects' needs during tender evaluation. The evaluation of PSC is only performed after the prequalified contractors have submitted their formal tender (i.e. after the prequalification stage).

The observed PC are arranged in descending order of LIA according to their observed frequency and importance as cited in the literature. This exercise enabled an early understanding of client and commentator preferences in this respect and also served as a basis for designing and initiating the industry-wide initial survey.

Chapter 4: A Review of UK Contractor Prequalification Practices

This chapter describes the research methodology used (for all the empirical surveys i.e. method of data collection and sampling survey method) and analyses of the accrued data of current contractor prequalification practices via initial survey. Opinions regarding prequalification preferences are also investigated. A discussion of present-day prequalification practices is presented; in particular it contrasts the use of 'in-house' and 'standard' prequalification practices.

Chapter 5: Analysis of Contractor Prequalification Criteria

This chapter discusses the questionnaire design of the second (industry-wide) survey. Findings of this survey (PC) are discussed and analysed via detailed statistical treatment.

Chapter 6: Analysis of Contractor Evaluation Criteria

This chapter describes the analyses of PSC. However, the emphasis here is on discussion of clients' selection preferences and opinions with regard to PSC. The alternative to comprehensive tenderer evaluation i.e. 'lowest price' selection options is also discussed. The influence of increased practitioner awareness of a multi-criteria approach to the contractor selection process is investigated, which jointly serves as the rationale for a new selection approach to current selection practices. Interpretation of the statistical outputs yielded an initial indication of construction clients' selection preferences (e.g. final selection preferences and tender evaluation methods).

Chapter 7: The Multivariate Discriminant Analysis Technique

This chapter describes the MDA technique used for developing a contractor classification model(s) (where PSC and their respective LIA from independent variables). The main aim of using this technique is to ascertain discriminant factors i.e. PSC, that influence contractor performance to derive a linear combination function for contractor classification purposes. Discussion of MDA also highlights the prerequisites for computing a discriminant model and previous studies of this technique in construction-related research are also considered.

Chapter 8: Z_1 Model for Contractors' Time, Cost and Quality Performances

This chapter describes the implementation of the MDA techniques in the context of developing a contractor performance (i.e. *good* or *poor*) classification model (i.e. Z_1 score) based mainly on the discriminant factors of contractors' *time*, *cost* and *quality* performances from 48 case studies. This chapter also investigates and demonstrates the effectiveness of the MDA technique prior to the subsequent discriminant analysis of the main classification model (i.e. Z_2 score), based on 31 discriminant factors.

A fully worked, MDA analysis is presented to demonstrate how the discriminant mechanism can redress and identify contractor performance characteristics (i.e. time, cost and quality). The Z_1 model was validated using 20 independent samples; as a test for its accuracy and effectiveness for use in classification and prediction purposes. This chapter also discusses how MDA can accurately deliver the classification results i.e. to achieve the main aim of the research.

Chapter 9: Discriminant Model for Project-Specific Criteria

This chapter discusses the development of a second (main) discriminant model (i.e. Z_2 score) for classifying contractor performance (*good* or *poor*) based on the identified 34 PSC and their respective LIA from 48 case studies of completed construction projects. Detailed descriptions of the main discriminant analysis, and its constituent variables, relationships between the variables and contribution of each variable to the MDA model are also encompassed. The validity and quality of the derived MDA models and potential improvement to the classification models is discussed and critically analysed.

Chapter 10: Summary, Conclusions and Recommendations for Future Research

A summary of the research is presented, together with recommendations for future research in the subject area. The principal findings of the research are discussed and conclusions drawn.

1.8 SUMMARY

Generally, contractor failure(s) can only be seen after the event, i.e. after a contractor has failed to perform on a project. This is costly to all concerned and often takes a long time to rectify. There are several methods available for investigating the issues of whether a contractor will perform adequately, these include qualitative and quantitative studies of contractor capabilities including financial, technical and managerial aspects. However, the best solution is early prevention, i.e. to select a competent contractor at the outset. Thus, robust **evaluation** of contractor capabilities and **classification** of contractors into *good* and *poor* performance groups becomes necessary before a contract is awarded.

This research concentrates upon UK construction clients' selection practices, and their preferred selection criteria (i.e. those which, based on experience, made them feel confident in entrusting the project to a contractor). The study also focuses on standard practices within the selection process, and how this can minimise costs incurred by clients, especially in the public sector, as well as to contractors. This is particularly important, in that the majority of public works are still awarded to contractors based on individual 'in-house' selection practices and the 'lowest-price wins' principle.

CHAPTER 2

OVERVIEW OF THE UK CONSTRUCTION INDUSTRY

2.0 INTRODUCTION

The UK construction industry has long been criticised for being slow to adopt new management techniques and for its high incidence of project time and cost overruns (Egan, 1998; Bates and Sturges, 1999; Poon *et al.*, 1999). This chapter provides an overview of the UK construction industry to explore and better understand these issues. The intrinsic link between the appointment of a main contractor and tender award practices are also discussed. This is followed by the promotion of good practice regarding the award of contracts, particularly, in the context of contractor selection.

2.1 A SNAPSHOT OF THE UK CONSTRUCTION INDUSTRY

The UK construction industry contributes an average 8% to the Gross Domestic Product (GDP) of the UK, in terms of financial input, materials and employment (Keynote, 1999). The industry creates 1.3 million job opportunities and has accounted for £52 billion of output over the five years 1995-1999 (Tables 2.1 and 2.2). The industry also commissions and operates a huge amount of materials and machinery, often domestically produced, and offers professional training (i.e. information technology, managerial and financial) to the overall UK economy (*ibid.*).

There has been a clear trend of increased construction activity in the UK. According to a recent survey by the RICS (1998), construction output increased for the seventh consecutive year since 1991. Even though there are growing signs that construction demand may be slowing down, the industry is still backed up by substantial workloads from future repair and maintenance works (i.e. railways, undergrounds, the health service, education), as well as government Private Finance Initiative (PFI) projects (i.e. prisons, health services, roads and infrastructure projects) (*ibid.*).

Table 2.1: Output of the UK Construction Industry (1995-1999)

	1995	1996	1997	1998	1999	
Output (£ million)	52643	55243	58352	62060	15638[b]	16013[b]
GDP[a] (£ million)	712548	730767	756430	773380	194564	195802
Outputs as % of *GDP	**7.4**	**7.6**	**7.7**	**8.0**	**8.0**	**8.2**

Source: Keynote (1999)
[a] *Gross Domestic Product at market and current prices.*
[b] *Provisional (first and second 3 months)*

Table 2.2: Personnel Employed in the Construction Industry (000's): 1995-1999

	1995	1996	1997	1998	1999
Public Sector	125	106	96	93	83[a]
Private Sector	549	551	584	636	657[a]
Self-employed	621	625	593	518	522[a]
Employees not on register	80	87	112	183	156[a]
Totals[b]:	**1375**	**1370**	**1,384**	**1428**	**1417[a]**

Source: Keynote (1999)
[a] *Provisional to July 1999*
[b] *Do not sum due to rounding*

In general, the positive trends (of UK GDP and employment figures) optimistically point toward sustainable demand and output for the industry. However, construction performance lags far behind other industrial sectors, for example, the automobile industry (MPA, 1994). This issue of disparity between construction and manufacturing output and productivity has been well documented and discussed in construction research (e.g. Chau and Lai, 1994; Nesan and Holt, 1999; Proverbs *et al.*, 2000). It is suggested that, increased problematical issues from both internal and external sources are likely to decline the prospect of improved overall construction performance (Latham, 1993;1994; Lowe, 1997; Winch, 1998; Keynote 1999). Some examples of these problems include:

Internal factors such as:

- fragmentation;
- entrenched adversarial attitudes;
- a large number of self-employed operators and small contractor firms (Table 2.2);
- an inherent dispute / culture of conflict within the industry; and
- a relatively high number of bankruptcy / insolvency of contractors.

External factors such as:

- an industry that is too sensitive to macro-economic changes;
- lack of training and too few qualified personnel;
- declining quality building land and its increased cost;
- increases in materials and (building) land prices, and reduction in financial aid to small and medium-sized firms; and
- increased competition from overseas contractors.

All-in-all, these combined internal and external factors exert substantial pressure on construction firms to remain buoyant in an industry renowned for low profit margins, whilst at the same time, demands and expectations from clients of the industry are constantly increasing.

2.1.1 A Problematic Construction Industry

As cited by Latham (1993), the construction industry has deeply ingrained adversarial attitudes and a culture of conflict. Construction professional practices have also been targets of criticism, albeit construction procurement and contract administration have long attempted to implement good practices (Simon, 1944; Banwell, 1964; Latham, 1994; HMSO, 1995; Egan, 1998). This appears to be much in evidence by the number of insolvencies of construction firms; which have averaged more than 12% of overall company failures in England and Wales (and 18% in Scotland) for the eight consequent years from 1992 to 1999 (Tables 2.3 and 2.4). Owing to these problems, construction industry performance continues to be perceived as being inefficient and has led to a deterioration in public confidence (Latham, 1993; Egan, 1998).

Table 2.3: Company Insolvencies in England and Wales- Industrial analysis

	1992	1993	1994	1995	1996	1997	1998	1999
Agriculture & Horticulture	191	157	166	99	89	51	65	75
Manufacturing	5449	4590	3608	2847	2740	2469	2493	2576
***Construction**	***3830***	***3189***	***2401***	***1844***	***1610***	***1419***	***1325***	***1529***
Transport & Communication	1261	1082	774	706	682	540	504	443
Wholesaling	1246	1012	994	966	707	539	563	619
Retailing	2477	2005	1711	1568	1419	1242	1153	1254
Services	4316	3748	2843	2415	2430	2248	2344	2511
Others	5610	4925	4231	4091	3784	4102	4756	5273
Totals:	24380	20708	16728	14536	13461	12610	13203	14280

** Percentage of insolvencies from 1992 to 1999 are: 16%; 15%; 14% 13%;12%;11%;10%;and 11%.*
Source: DTI (1998a)

Table 2.4: Company Insolvencies in Scotland - Industrial analysis

	1992	1993	1994	1995	1996	1997	1998	1999
Agriculture & Horticulture	6	10	3	2	11	6	11	5
Manufacturing	176	141	89	78	90	117	125	104
***Construction**	***133***	***109***	***94***	***90***	***68***	***62***	***104***	***108***
Transport & Communication	24	17	18	17	21	20	24	16
Wholesaling	39	19	17	19	21	22	29	35
Retailing	92	73	55	71	20	35	28	48
Services	93	90	95	56	55	69	92	83
Others	107	92	73	108	155	146	153	173
Totals:	670	551	444	441	441	477	566	572

** Percentage of insolvencies from 1992 to 1999 are: 20%; 20%;21%;20%;15%;13%;18%;and 19%.*
Source: DTI (1998b)

Apart from the adversarial attitudes and fragmented structure of the industry, traditional procurement practices have been criticised for their inadequacy and inefficiency when dealing with the increased complexity of construction technology and more stringent demands from clients. Many industry practitioners are expressing a lack of confidence in the use of 'conventional' procurement routes and a series of reports and recommendations have been published underlining this situation (e.g. Simon Committee, 1944; Higgin, 1964; Banwell, 1964; Mobbs, 1976; Carpenter, 1981; Chern and Bryant, 1984; Latham, 1994; Rwelamina and Hall, 1994; Egan, 1998). Banwell, Higgin and Chern and Bryant (*op. cit.*) criticised traditional project delivery systems as being inefficient, creating adversarial relationships and a 'conflict' culture, whilst also engendering fragmentation among clients, designers and contractors. Such criticism has inevitably primed the emergence of modern procurement routes and contractual approaches, designed in part, to deal with these problematical issues.

In the early 1990s the UK construction industry showed an increased use of alternative procurement and contractual frameworks (Davis Langdon & Everest, 1992;1994). Nevertheless, according to CIRIA (1995), contractual documents and procurement methods are merely tools for managing risks. Many of the new and 'standard' procurement options were chosen mainly for their risk 'distribution' characteristics (*ibid.*). This indicated that most industry practitioners start with consideration of procurement strategy, when in reality, greater attention should be placed on achieving client satisfaction and the need to accomplish clients' specific needs (Kumaraswamy, 1999). Without doubt, there is a tendency to underestimate the main contractor's contribution to a project and the potential influences (both positive and negative) that a contractor can bring to achieving 'project success'. This evidence underlines the need for reliable selection of a 'good' main contractor (Holt, 1995a). In this sense a 'good' contractor can be described as one who is able to complete a contract on time, within budget, and achieve the required levels of quality to ensure client satisfaction[1].

Liu and Cheung (1994) described contractual arrangements as a means of risk distribution. In principle, this is not the ultimate objective in procuring construction work (CIRIA, 1995). Love *et al.* (1998) described that to select a suitable procurement route is vitally important, it is a key factor contributing to *overall* client satisfaction and project success. However, it should be pointed out that selection of the correct procurement route option is no 'guarantee' of project success (Rowlinson and Newcombe, 1988). In other words, project success should take account of all participants within the industry, irrespective of what type of delivery system will be selected. Therefore, the 'human aspect' in this context plays a vital role. The industry expends large amounts of effort in developing holistic and systematic approaches to minimising (or equitably apportioning) the potential risks of a project, yet fewer focus on the success 'factors' in selecting a suitable and competent contractor to ultimately perform the whole construction process (*ibid.*, Liu and Cheung, 1994).

2.1.2 Appointment of a Main Contractor in Construction Procurement

In the good practice guide produced by the IOB (1976) it was cited that selection of a 'good' contractor is essential. However, over the past three decades, the prime consideration in selection of 'good' contractors has been little emphasised in contract

[1] Contractor performance in time, cost and quality discussed in Chapter 8. Chapter 9 discusses 34 performance factors in more details.

award practice (Holt *et al.*, 1995a). Obviously, final selection of a contractor is deep-rooted in the 'lowest-price-wins' principle, often, without further contractor scrutiny (Merna and Smith, 1991; Holt, 1995). Consequently, no matter how good the procurement approach, the construction works are easily 'jeopardised' by poorly (selected) contractors.

Poor contract award practice in the UK construction industry has long been recognised (Holt *et al*, 1995a). Some of these 'poor' aspects include: the traditional approach of the lowest bid concept, subjective contractor evaluation methods, "Dutch auctioning", non-standard questionnaires for prequalification, and the fact that lengthy tender lists can trigger tendering anarchy in the UK construction industry (Klein, 1994). Such aspects have a negative impact on the industry. It inhibits the dissemination of good practice (i.e. standardisation) and often conflicts with recommendations from construction professional bodies, particularly, in the public sector construction (Latham, 1994; Merna and Smith, 1990; Holt *et al*, 1995a; Wong *et al.*, 1999a).

Since the 1950s, a series of construction reports have given a tremendous amount of attention to the contracting problems, and have provided recommendations on how to select a *good* contractor (Simon committee, 1944; Banwell, 1964; Latham, 1994; Egan, 1998). These reports recommended the use of disciplined approaches to overcome the deficiencies of current selection practices; while keeping a watching eye on the changing construction environment. Since the Simon Committee Report (1944), many studies on contract award practice have been conducted (e.g. Banwell, 1964; IOB, 1979; ICE, 1980). Issues bringing about the change away from 'open tendering' to 'selective tendering' were highlighted (Banwell, 1964). Banwell (1964) recommended several changes toward contractor selection including greater use of 'unorthodox' methods (e.g. negotiation, selective tendering methods and so on). Moreover, in Latham's recommendations (1994) a single, central UK contractor register for all public agencies was recommended. Such recommendations provide basic guidance to good practice for the construction industry, particularly in the public sector. This is because significant reductions in time and cost reduction can be made, eliminating (unnecessary) duplication in the prequalification process and objective evaluation during the selection process. However, as will become apparent later in this thesis (i.e. Chapter 4) a single register is far from being the panacea to such ills in this particular context.

2.2 A REVIEW OF CONTRACTOR SELECTION AND CONTRACT AWARD PRACTICE

The issue of appointment of a main contractor via traditional contractual arrangements has triggered much attention and criticism from the construction industry commentators. Since the 1940s, the UK construction industry has witnessed significant changes in the way contracts are procured and managed (e.g. Simon Committee, 1944; Banwell, 1964; Latham, 1994; Egan, 1998). As will be shown in the following section, discussion of this issue focused on the traditional contract award practices, the recommendation of standardisation and the growth of interest in partnering approach in the context of contractor selection, in the UK construction industry.

2.2.1 The Simon Committee (1944)

The increasingly complex, varying demands and supply workload of the construction industry have dominated contract award practices (Hatush, 1996). This impacts the contractor selection decision regardless of type of procurement route used (*ibid.*). Early modes of tendering placed emphasis on tender price as the dominant influence in the final selection decision (Merna and Smith, 1990; Holt *et al.*, 1995a). This is, (and to a greater extent remains) particularly so in the public sector where statutory requirements and 'standing procedures' are implemented to protect the taxpayer from extravagance, corruption and other improper practices by public officers (Lewis, 1981; Harp, 1990). In order to meet statutory requirements, 'open tendering' (i.e. free competition) was widely adopted (*ibid.*). The essence of competitive tendering generally requires:

i. preparation of plans and specifications for the work;
ii. public advertisement to invite submissions;
iii. formal submission of tenders;
iv. evaluation of the contractors' proposals;
v. consideration of proposals under statutory requirements (i.e. the possible lowest-price tender); and
vi. award of contract to the (normally lowest priced) contractor.

This practice is well known, but, it is also accepted as 'normal' to expect a contract to run into problems of time and cost overruns under such a regime. This is mainly because the initial intense competition forces contractors' prices down, so any 'opportunity' to make up this 'loss' becomes a 'claim' for extras, being submitted to the client. Often this leads to time-consuming conflict and ultimately litigation (Lewis, 1981; Holt, 1995). Many industry practitioners and commentators agree with this causal relationship (e.g. Hunt *et al.*, 1966; Merna and Smith, 1990; Latham, 1993).

In the Simon Committee Report (1944), some notable recommendations were highlighted in the context of contractor appointment. The report condemned the traditional way of selecting a main contractor (i.e. emphasis on lowest price tender). The system of accepting the lowest price is less than optimal because it brings unfair pressure and competition on to the 'good' contractor, encourages unscrupulous methods by builders (to try and 'save' money), accelerates poor workmanship and reduces overall builder quality (Vorster, 1977; Lewis, 1981). The report stressed that the only way to guarantee a competent and honest builder is through fair price competition, and by limiting the number of tenderers (i.e. carefully selected qualified contractors). Such contractors should have the basic competence as required for the proposed works (Simon Committee, 1944:p16).

The report recommends construction clients keep a contractor 'approved list' / 'standing list' from which to abstract firms, to invite to tender. That way, the selection process will be able to reduce time and cost problems during project implementation. The report also highlighted the unnecessary burden of time and effort in the preparation of tenders and evaluation of tenderers, particularly, when the number of contractors involved in tendering were not restricted. These points were later advocated and expanded by several construction commentators and reports (e.g. Higgin, 1965; Banwell 1964; IOB, 1974).

2.2.2 The Banwell Report (1964)

A number of significant proposals with specific reference to contractor selection were suggested in the Banwell report (1964). *Selective tendering* and *fair price* selection were strongly advocated. The report also strongly advocated *selective* tendering over *open* methods. It was also pointed out that the appointment of contractors via *serial tendering* offered benefits to both the client and contractor. For example, this approach provides opportunity for continuity of workload to the contractor, and time savings for repeating the process when having a series of similar contracts (i.e. only one learning-curve and economies of scale). Appointment of a contractor via the serial tendering method was also discussed in the Latham report (1994). Latham significantly highlighted the use of 'partnering' and standardisation in contractor selection practices.

2.2.3 The Latham Report (1994)

In 'Constructing the Team', Latham (1994) highlighted the need for a central UK prequalification system (register), particularly, for use in the public sector. Greater standardisation of prequalification procedures and documentation was recommended to improve construction contract award practices. Latham (1994) also discussed *qualification* and *prequalification* systems. The report advocated that prequalification is an effective system allowing clients to select a contractor who mirrored the size, capability and experience required for the proposed work. Latham defines 'qualification' as that exercise performed for a contractor to get on to an approved list, and 'prequalification' as meaning to draw up a list of contractors suitable for a particular project.

Latham highlighted the different qualification lists maintained in the Department of the Environment (DoE) and the Department of Transportation (DoT) which were said to have inevitably increased (and duplicated) the time and cost of contractor selection efforts in public sector works. Such as the use of the *Contractor Management Information System* (CMIS) and *Register of Consultants* (ConReg) qualification systems, Latham believed that standardisation of contractor prequalification was essential, since it makes a significant contribution to achieving a real cost reduction in project cost by eliminating duplication of prequalification and evaluation efforts. Latham advocated the rationalisation of selection procedures by preparing a national single qualification document for those who intended to tender for public sector works.

Latham's recommendations were later implemented by the Construction Industry Board (CIB) Working Groups (4 and 5) in 1996. The groups studied how the existing registration systems, i.e. ConReg (Consultants Register) and CMIS (Construction Management Information System) could be developed into a UK standard system, for all public and clients representatives to use during the selection process. Two subsequent reports: 'Framework for a national register of consultants'; and 'Framework for a national register of contractors' were published (CIB, 1997a;1997b). These reports provided specific considerations for appointment of consultants and contractors. The promotion of standard practices was also strongly recommended by the Department of Environment, Transport and Region (DETR[2]).

[2] DoE and DoT merged to become DETR in June 1997.

The DETR produced an *Action Plan* for implementation of standard prequalification practices, and established an Advisory Group which comprised existing and potential users of the 'standard' prequalification system and industry representatives. The *Constructionline,* a government-sponsored service was subsequently developed, based on the National Qualification System (NQS) database. Constructionline was opened to the wider public sector in April 1997 and was fully privatised to new independent operators i.e. Capita Business Services Limited in July 1998 (DETR, 1997;1998). With the publicity and encouragement from CIB, Capita continues to play a vital role in promoting consultants and contractors who are qualified to undertake work for UK public and private sectors clients.

2.2.4 The Egan Report (1998)

The Egan report (Egan, 1998) was published to review the Latham (1994) recommendations and examine the impact that the report had on the UK construction industry, and any other developments arising from it. In the context of contractor selection, Egan cited there should be reduced reliance on competitive tendering by implementation of an effective partnering approach. The Egan report also outlined the need for selection of 'quality' partners (i.e. contractors) based on the criteria of:

i. overall value for money rather than selection of lowest price partners;
ii. quantitative measures of contractor performance; and
iii. contractors' team-working and innovation abilities i.e. those that offer efficient solutions, and the sharing in success (i.e. cost savings).

Egan believed that if these criteria were satisfied then the industry could cut costs, by a substantial reduction in tendering fees.

2.3 SUMMARY

The UK construction industry is unique in its methods of working. Fragmentation, increased complexity, the use of a wide variety of procurement routes and fierce competition are typical traits of the UK construction sector.

A number of reports and investigations have been published offering suggestions for changes to traditional construction practices and procedures (e.g. Simon Committee, 1944; Higgin, 1964; Banwell, 1964; Mobbs, 1976; Carpenter, 1981; Chern and Bryant, 1984; Latham, 1994; 1994; Egan, 1998). In spite of these, the industry has not moved forward to any significant extent (Merna and Smith 1990; Holt *et al.*, 1995a; Wong *et al.*, 2000c). It is suggested that such problems are largely due to the fact that the industry has long acted independently and is inherently fragmented in nature (Mobbs, 1976; Carpenter, 1981; Chern and Bryant, 1984; Latham, 1993; Rwelamina and Hall, 1994). This can be seen from the Pre-1950's construction practitioners' criticisms and recommendations from the Simon report (1944), in that a majority of projects awarded were via open tendering methods.

Notwithstanding the criticism emanating from the series of reports produced over the last 50 years, prequalification in contract award practices has yet to be standardised. This point has been reinforced recently by Latham (1994) and by the author (e.g. Wong *et al*, 1999;2000c).

Existing prequalification practices are still very much fragmented. This is predominantly due to the industry's traditional conventions and inflexible contracting practices (Wong *et al.*, 2000c). From this evidence, it is clear that to promote economy and efficiency in construction, participants should exhibit coherent interest and greater collaboration between all parties.

Appointment of a contractor has the potential to have a profound effect on the overall success of a project. However, conventional methods such as competitive tendering, the low bid concept and 'traditional' selection approaches, are still inherent in the industry and do not contribute to the recommendations made, time and again, in the reports cited above.

To summarise, it has been identified that, not only do existing contractor selection practices need to change, but moreover there is a need to enhance remedial measures (e.g. use of a single national qualification system) and recommendations (e.g. a 'standardised' contractor selection and evaluation procedure) advocated in the earlier discussed series of construction reports. By implementing such measures the contractor selection burden would be reduced and subsequently an improvement in construction productivity and efficiency would be achieved. It is one of the objectives of this research to identify the deficiencies in present contractor selection practices (as have been discussed earlier). The following chapters discuss an in-depth study of UK present day selection preferences and opinions pertaining to the use of standard selection practices.

CHAPTER 3

LITERATURE REVIEW

3.0 INTRODUCTION

One of the fundamental prerequisites to successful contractor selection is an appropriate set of determinant criteria (i.e. selection criteria) that can be used against which to compare and predict contractors' likely performance (Russell and Skibniewski, 1988; Hatush, 1996; Ng *et al.*, 1999). Thus, the study of contractor selection criteria both in terms of quantitative and qualitative aspects is of vital importance (*ibid.*).

Contractor selection criteria are discussed in this chapter. A detailed literature review identifies a set of the most frequently used criteria in the contractor selection process. The findings of this literature study identified key contractor attributes used in the evaluation and selection process i.e. the most eminent *prequalification criteria* (PC) and *tender evaluation criteria* (or more specifically *project-specific criteria*, PSC).

The detailed literature review of PC and PSC is undertaken retrospectively over the last four decades in order to provide a cross-comparison. The rationale being towards identifying the most prudent selection criteria (both PC and PSC), for use in the proposed industry-wide questionnaire surveys and in the development of a contractor classification model which are to be discussed later in this thesis.

3.1 CONTRACTOR PREQUALIFICATION CRITERIA

An important decision facing a construction client is to select a 'good' contractor. Poor contractor selection can bring disaster to a project (Russell and Skibniewski, 1988; Russell *et al.*, 1992). Further, adverse client / contractor relationships tend to ensue if the 'wrong' contractor is chosen (IOB, 1979). A variety of prequalification and evaluation procedures are available for use in different circumstances, for instance, different types of: projects; clients; cost; and / or size of project (Russell *et al.*, 1987;1989; Holt, 1998a). Many have evolved from research and been rationalised for use in different selection settings (e.g. Diekman, 1983; Nguyen, 1985; Juang *et al.*, 1987; Russell and Skibniewski, 1990a;1990b; Moselhi and Martinelli, 1990; Hatush and Skitmore, 1997c). This confirmed a growing recognition of the need for a systematic and objective approach towards contractor selection and evaluation (Potter and Sanvido, 1994; Ng and Skitmore, 1995; Holt *et al*, 1995a; Wong *et al.*, 1999).

The PC used by procurers during prequalifying tend to be those pertaining to investigation of (Russell and Skibniewski, 1989; Holt *et al.*, 1994a; Hatush and Skitmore, 1997b):

i. contractors' technical expertise;
ii. financial soundness;
iii. managerial capabilities;
iv. health and safety performance; and
v. past performance records.

These criteria (should optimally) reflect the objectives of procurers and the needs of the project. Ng *et al.* (1999) found a significant difference between the levels of importance emphasised (i.e. among PC) for different types of prequalification practices. Where the perceived level of importance for a given criterion differed from other(s), then it was determined that this was mainly because of the differences in training and expertise of each prequalifier.

The following sections of this chapter are concerned with identifying a set of PC for use in contractor prequalification process prior to invitation-to-tender with an emphasis on building and civil engineering works respectively.

3.1.1 Good Guidance Documents

In response to the Banwell report (1964) many *standard forms* and *good practice guides* for contract award emerged. For instance: the National Joint Consultative Council (NJCC) practice panel; JCT standard forms of contract; and the Royal Institute of British Architects (RIBA) Plan of Work. Banwell was a catalyst for much subsequent investigation into this field (Holt, 1995). In the late 1970's the Institute of Building (IOB, 1979) documented good practice for contractor selection and general tendering procedure. It was recommended the following contractor evaluation criteria be used: *financial stability; ability / competence to complete the project; adequate resources; management skills;* and *previous experience.* Guidance on the preparation, submission and evaluation of tenders for civil engineering works was similarly produced by the Institution of Civil Engineers (ICE) Conditions of Contract Standing Joint Committee in 1980 (ICE, 1980). Their PC were: *financial standing; technical ability; organisational ability; similar experience; third parties' / referees*; and (contractor's) *past performance.* Key matters such as: *insurance; alternative design proposals; approximate commencement date;* and *project completion time* were also recommended for consideration by the ICE.

The increased use of prequalification has also been witnessed in the Australian construction industry. Earlier recommendations of the *No Dispute* document (Anon, 1990) published by the NPWC[1] / NBCC[2] recommended that prequalification should be subject to regular updating and be based on the contractors having: *minimum of two years' profitable operation; financial capacity to undertake project; plant, machinery* and *staff resources to undertake the project; list of previously completed projects;* and *list of current contracts.* These initial recommendations were further developed by the Construction Industry Development Agency (CIDA). A document titled 'Pre-qualification Criteria-The Australian Construction Industry' was issued by CIDA (1995). This guidance advocates seven major criteria for contractors to be measured against, these being: *technical capacity; financial capacity; quality assurance; time performance; occupational health* and *safety; human resource management;* and *skill information.*

Codes of procedure produced by The National Joint Consultative Committee for Building (NJCC), include: (1) Code of Procedure for Single Stage Selective Tendering (1994a); (2) Code of Procedure for Two Stage Selective Tendering (1994b); (3) Code of Procedure for Selective Tendering for Design and Build (1985); and (4) Code of Procedure for Selective Tendering for Selection of a Management Contractor (1991).

[1]NPWC- National Public Works Council (Australia), established in 1967, renamed in March 1997 becomes APCC- Australia Procurement and Construction Council, a peak council of Departments responsible for procurement and construction policy of the Australian Federal, State and Territory Governments.
[2]NBCC- National Building and Construction Council (Australia).

Code (1) is suitable for traditional short-list single stage tendering, whilst code (2) is appropriate for larger or complex schemes where a joint intellectual effort between contractor(s) and design team(s) is required during the design stage. Code (3) takes account of a contractor being responsible for completing the design of the project, and Code (4) is suitable for public or private clients considering the construction management procurement option. All codes recommend that contractor selection starts with a short list being drawn up, based on either a client-approved list, or from an ad-hoc list in compliance with contractors' acceptable levels of skill, integrity, responsibility and proven competence for work of the character and size proposed. Selection from the short-list should consider: *financial standing / record; recent experience* at the required rate of completion over a comparable contract period; *general experience* and *reputation; management structure* for the type of contract envisaged; and *adequate* capacity at the relevant time. Contractors' recent experience of designing and constructing is required by code (3).

The codes (i.e. codes (1) to (4)) were subsequently superseded and replaced by the 'Code of Practice for the Selection of Contractor ' produced by the Construction Industry Board (CIB, 1997c). The latter focused on: *managerial capabilities, financial resources, quality performance, health and safety criteria, past performance; capability to undertake design;* and *ability to innovate* for selection of a main contractor.

Clearly, clients have used a wide range of prequalification criteria over the past four decades. To summarise these, most of the good practice documents recommended that prequalification criteria should be based on: *contractors' managerial; technical; financial; past performance / experience;* and *health and safety* aspects.

3.1.2 Empirical Research

Prequalification criteria used in the UK and USA construction industries have changed little over the past two decades (Russell and Skibniewski, 1988; Merna and Smith, 1990; Holt *et al.* 1994a;1994b; Hatush and Skitmore, 1997b). This is despite the advent of more complex procurement systems and increasing complexity of projects (*ibid.*). Russell and Skibniewski, Merna and Smith and Holt *et al.*, (op. cit.) all outlined PC in use and found emphasis on *financial stability; managerial capabilities; past performance; health and safety;* and *technical ability.* This situation was reinforced by Hatush and Skitmore (1997b), who underlined the necessity to objectively quantify criteria based on the five major groupings of: *general information* (for administrative purposes); *financial information; technical information; managerial information;* and *safety information.*

Bubshait and Al-Gobali (1996) investigated Saudi-Arabian semi-private and private construction firms. A set of commonly used criteria was revealed; being very similar to the results obtained from the US (Russell *et al.*, 1992). Table 3.1 shows the comparison of PC use in Saudi-Arabian and US construction projects. This may indicate that changing geographical market and social-economic conditions do not affect PC, albeit such assertion can not be considered definitive on this evidence alone.

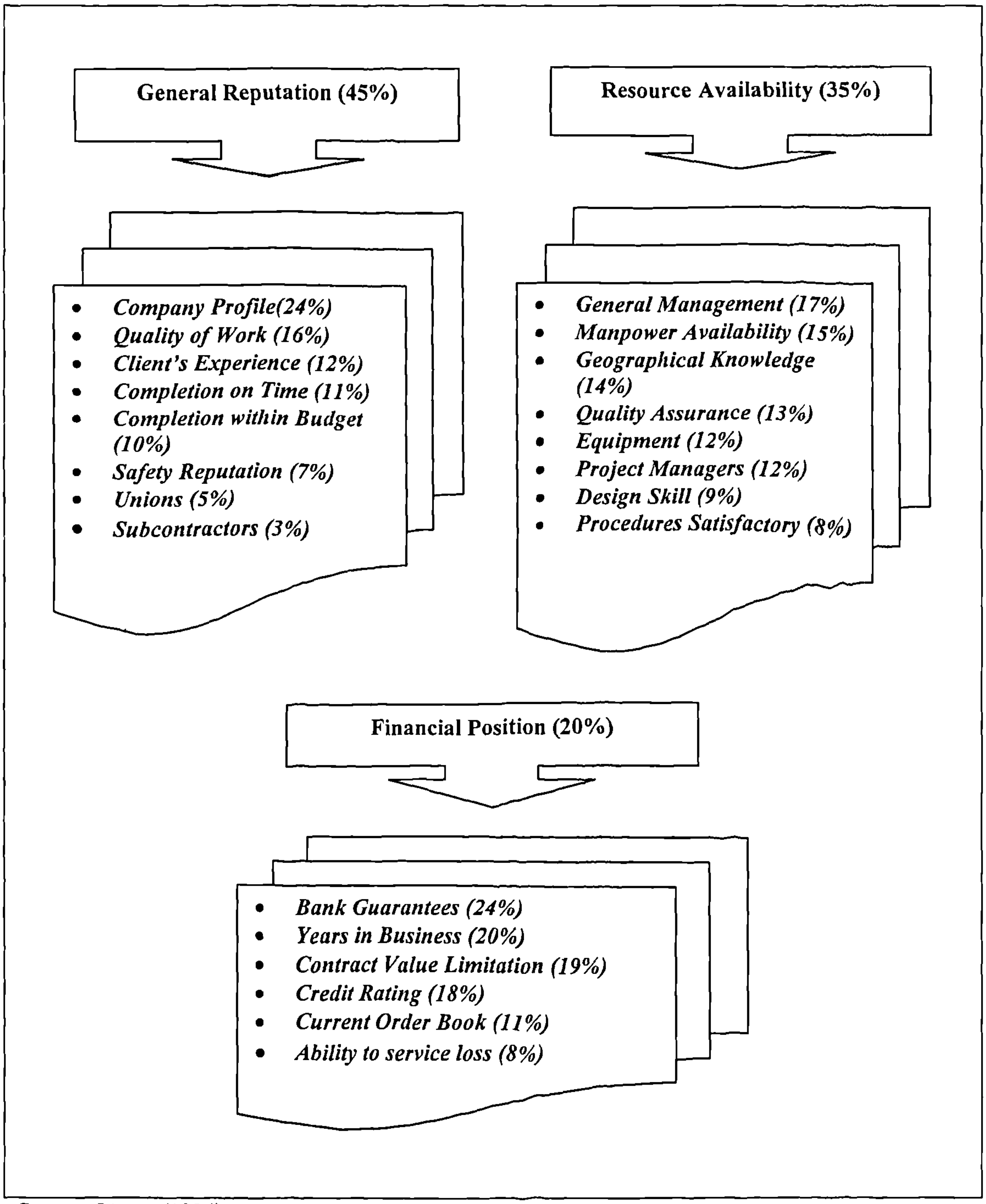
Table 3. 1: Comparison of PC Impact Index: Saudi Arab and US

	Kingdom of Saudi Arabia		*US*	
Prequalification Criteria	*Weight*	*Rank*	*Weight*	*Rank*
1. Experience	3.746	1	3.655	1
2. Financial stability	3.619	2	3.631	2
3. Past performance in owner's previous projects	3.429	3	3530	4
4. Quality assurance & quality control programme	3.365	4	3.360	5
5. Project Management capabilities	3.317	5	3.030	6
6. Contractor failure to complete a contract	3.270	6	3.560	3
7. Management staff available	3.175	7	2.918	8
8. Capacity of contractor	3.063	8	2.991	7
9. Contractor organisation	2.984	9	2.357	12
10. Workforce resources	2.968	10	2.553	11
11. Equipment resources	2.825	11	2.110	15
12. References	2.746	12	2.808	9
13. Amount of work performed earlier	2.730	13	2.200	14
14. Current workload	2.603	14	2.673	10
15. Experience in geographical location of project	2.254	15	2.210	13
16. Location of home office	1.952	16	1.460	16

Source: Bubshait and Al-Gobali (1996)

Prequalification criteria have been extensively investigated in an Australian context (e.g. Liston, 1994; Anon, 1990; CIDA, 1995). According to Liston (1994) the prequalification procedure is essential since the objective is to allow a client to maintain consistent analysis of contractor ability and also to provide auditable records. Liston conducted a questionnaire survey for the use of PC in Queensland (*ibid.*). The survey derived the most prominent PC and their ranking for public sector and semi-public sector civil engineering works. The results are as shown in Figure 3.1. Liston summarised these most prominent PC into three main groups i.e. *general reputation; resources available;* and *financial position.*

Figure 3. 1: Use of PC in the Australian Construction Industry



Source: Liston (1994)

To summarise previous empirical research, those criteria highlighted can be grouped under five categories, viz.; *general information* (i.e. reputation, financial information, resources)*; technical ability; managerial information;* and s*afety information.* These major groupings are commonly used, but differences in the levels of importance attached to them can occur stemming from clients' preferences and project characteristics.

3.1.3 Experts' Opinions

Tendering practices in Northern America have been well publicised (Hunt *et al.*, 1966; Diekman, 1983; Nguyen, 1985; Russell and Skibniewski, 1988; Bastidas, 1984; Herbsman and Ellis. 1992). Hunt *et al.* (1966) contended that prequalification should first investigate whether a contractor is 'qualified' to build a project with specific resource demands; they must satisfy the requisites of *skill, experience, necessary facilities, financial resources* and *experience appropriate to the proposed construction method.*

Diekman (1983) stressed that project success depends on the contractors' skill, reputation and experience rather than price. Diekman's PC were: *cost exposure; financial stability; company stability* and *reputation; managerial capability; organisational attributes; historical performance;* and *quality performance.*

Dennis (1993) recommended that prequalification should consider: *financial strength to sustain cash flows; experience / competency; plant capability; technical capability (including human resources); a complete understanding of proposed projects* and *ability to absorb subsequent changes; experience to understand commercial requirements of the contract* and *associated implications;* and *compliance with health* and *safety regulations.*

3.1.4 Summary of the Literature Findings Concerning PC

Based on the literature review, criteria may be grouped under five categories, viz: (i) *organisational / general information;* (ii) *managerial;* (iii) *financial;* (iv) *technical capabilities;* and (v) *experience / past performance.* These major groupings are commonly used, but differences in the levels of importance attached to PC can occur stemming from clients' preferences and project characteristics. Table 3.1 shows a summary of contractor PC among the research discussed.

Experts and industry practitioners / commentators have suggested a wide range of PC. Many have underlined the necessity of an objective approach to quantify PC. Adequate objective evaluation will reduce the possibility of basing the early selection decision (compilation of tender lists) on subjective factors (e.g. long-term relationships, possible 'lowest-price' tender). Table 3.2 shows the observed 45 PC arranged in descending order of importance, according to the observed frequency that they were cited as important in the literature review.

The importance levels are indicative only, being based solely on number of times cited. A more definite description of importance will follow analyses of the survey data, later in this thesis. The literature review of PC firstly confirmed the use of different types of PC in the past four decades (and present practice) in contractor prequalification and identified significant disparity in levels of importance assigned for each PC in different selection settings (i.e. project and client types). Further, prequalification criteria considered prudent by commentators and practitioners have largely remain unchanged over the past four decades.

Table 3. 2: Comparison of Contractor Prequalification and Selection Criteria.

Prequalification & Selection Criteria	Hunt *et al.*, (1966)	Russell *et al.*, (1992)	Merna and Smith, (1990)	Holt *et al.*, (1994a)	Hatush and Skitmore, (1997b)	Total	Mean
Organisational / General:							
-Company size, age, image & reputation			◆	◆	◆	3	2.5
-Current workloads, health & safety				◆	◆	2	
-Home office & resources	◆	◆		◆	◆	4	
-Staff training regime				◆		1	
Financial:							
-Bank references / Financial statement		◆			◆	2	2.25
-Turnover				◆		1	
-Bonding capacity		◆				1	
-Financial capability	◆	◆	◆	◆	◆	5	
Management:							
-Key personnel & qualification		◆		◆	◆	3	2.5
-Management Capability	◆		◆			2	
Technical & Expertise:							
-Design resources, equipment and plants	◆	◆	◆	◆	◆	5	4.5
-Particular skills & technical expertise	◆		◆	◆	◆	4	
Experience & Past Performance:							
-Experience in particular work	◆	◆	◆	◆	◆	5	3.4
-Past performance & experience		◆		◆	◆	3	
-Time, cost & quality performance		◆		◆	◆	3	
-Dispute & claim history	◆			◆		2	
-Failure / success to complete the contract	◆	◆		◆	◆	4	

Table 3. 3: Prequalification Criteria for Building and Civil Engineering Works

	Building		Civil Engineering	
Prequalification Criteria	*Observed Frequency*	*Rank*	*Observed Frequency*	*Rank*
1. Financial stability	11	1.0	12	1.0
2. Experience in particular work type(s)	10	2.0	7	8.5
3. Quality and experience of key personnel(s)	9	3.0	6	11.0
4. Quality performance record	8	4.5	11	2.0
5. Resources (manpower/equipment/labour)	8	4.5	9	5.0
6. Management capability	7	7.0	7	8.5
7. Contractor success/failure contract record(s)	7	7.0	6	11.0
8. Contractor capability to carry out the work	7	7.0	4	17.5
9. Technical ability and expertise	5	11.5	10	3.0
10. Past performance in terms of time	5	11.5	9	5.0
11. Past performance in terms of cost	5	11.5	9	5.0
12. Location of home office/place for business	5	11.5	8	7.0
13. Company size and organisation	5	11.5	6	11.0
14. Reputation/Image	5	11.5	2	33.5
15. Health and safety (record/awareness)	4	16.0	4	17.5
16. Interface of contractor with others	4	16.0	4	17.5
17. Current work load	4	16.0	3	24.5
18. Contractor maximum capacity	3	22.5	4	17.5
19. Design ability	3	22.5	4	17.5
20. Experience: local or international	3	22.5	4	17.5
21. Contractor specific experience	3	22.5	4	17.5
22. Dispute and claim history	3	22.5	3	24.5
23. Employees and subcontractors details	3	22.5	3	24.5
24. Quality assurance and control procedure	3	22.5	3	24.5
25. References/third parties	3	22.5	2	33.5
26. Prior business relationship	3	22.5	2	33.5
27. Company nationality	3	22.5	1	42.5
28. Project management skills	2	32.5	5	13.0
29. Understanding of contract/legal issues	2	32.5	4	17.5
30. Risk management system	2	32.5	3	24.5
31. Ability to innovate	2	32.5	2	33.5
32. Insurance Cover	2	32.5	2	33.5
33. Site management	2	32.5	2	33.5
34. Past performance to particular project	2	32.5	2	33.5
35. Trade union record	2	32.5	2	33.5
36. Annual turnover	2	32.5	1	42.5
37. Contractor negotiation skill	2	32.5	1	42.5
38. Bonding capacity	1	41.5	3	24.5
39. Home office support	1	41.5	2	33.5
40. Number of years in business	1	41.5	2	33.5
41. Past performance in client's previous project(s)	1	41.5	2	33.5
42. Financial exposure (local or international)	1	41.5	2	33.5
43. Staff training regime	1	41.5	1	42.5
44. Environmental impact awareness	1	41.5	1	42.5
45. Credit rating	1	41.5	1	42.5

The observation (i.e. literature review) 'reinforced' and 'consolidated' the knowledge of 'essential' prequalification criteria and their levels of importance assigned for different selection settings; as a basis for initiating the subsequent empirical surveys (i.e. an initial and the main industry-wide survey).

3.2 TENDER EVALUATION CRITERIA

The evaluation of tenderers is performed once prequalified contractors have submitted their formal tender (Holt *et al.*, 1993). Frequently, this stage of the evaluation process is conducted by the client's scrutiny team, based mainly on their accumulated experience (Merna and Smith, 1990; Ng and Skitmore, 1955; Wong *et al.*, 2000b). The final selection decision therefore relies on a practitioner's knowledge and personal characteristics. Hence, the process is often influenced by individuals' experience and preferences (*ibid.*). Research into the evaluation of tenderers, using *project-specific criteria* (PSC) has received a minimal amount of attention in the UK construction industry, particularly, because clients rely on prequalification and subsequent 'lowest-price' tender as the best option for selection of contractor (Holt *et al.,* 1995a). In the context of this thesis 'PSC' refers to criteria that are used by construction clients' scrutiny team during tender evaluation. This principle is further discussed in Chapters 6 and 7.

The prime influence upon final selection decision has long been dominated by the 'lowest-price' principle (Hunt *et al.*, 1966; Baker and Orsaah, 1985; Merna and Smith, 1990). The findings of Baker and Orsaah (1988), Merna and Smith (1990) and Holt *et al.*, (1995a) have all outlined that final selection ultimately attaches importance to the 'low-price' criterion. A majority of construction clients rely on prequalification alone without any further scrutiny of contractors during final evaluation of tenderers (i.e. using PSC). Therefore, it would seem that final selection is often subjective, with comparison of tender prices being the only 'quantifiable' aspect (Merna and Smith, 1990; Holt *et al.*, 1994c;1995a).

Good practice guidance on evaluation of tenders for civil engineering works has been produced by the ICE Conditions of Contract Standing Joint Committee (ICE, 1980). It was stated that following identification of the lowest priced tender, contractors should be further scrutinised in terms of: *available resources; proposed site / headquarters; organisation; construction method proposed;* and via *third parties or referees.* Nevertheless, the ICE guidance also recommended that clients' interests are not necessarily met by accepting the lowest tender. Evaluation of tenders should also take into account other criteria such as *type of plant to be used, the likely financial out-turn of the project using a particular contractor,* and *ability to complete on time* (*ibid.*).

Apart from good practice guidance, detailed study of tender evaluation for civil engineering works was found in Horgan's (1984) investigation. This presented a 'contrasting' solution, making certain contractors more 'acceptable' to the client by using 'preference' criteria. It was suggested that contractors might be favoured:

i. to whom the employer has a duty or other benefit (e.g. mutual trade concessions);
ii. with whom the employer does considerable counter-business;
iii. with a good reputation on labour-relations;
iv. that have prior relationships with notable success; and
v. for whom the employer has a 'predilection'.

Horgon's recommendations would seem to indicate that it is prudent to consider contractors who have 'good' and prior relationships rather than a set of criteria recommended by good practice guidance (e.g. ICE , 1980; CIC, 1993; CIB, 1997c).

Moore (1985a;1985b) focused on evaluation of contractors for fast track projects. To evaluate contractors' proposals, it was suggested that a cost comparison be used. This comparison method consists of *Commercial Evaluation Factors* and *Project Execution Factors.* These factors aimed to broaden the scope of comparison parameters rather than simply identify the lowest tender. Moore further explained that project execution costs are directly related to the quality of project management (i.e. execution cost is much lower on well-run projects). Moore's evaluation criteria were: *craftsmen availability; training or skill level of craftsmen; foreman quality* and *training; productivity; system* and *procedures; field organisation; safety record; geographical experience (i.e. familiarities); specific experience; quality control; home office support; executive involvement; construction equipment; condition* and *procedures;* and *engineering co-ordination.*

Merna and Smith (1990) concentrated their research on public sector civil engineering works. They found that the 'low price' principle still dominated UK construction at that time and contractor selection relies significantly on prequalification. During tender evaluation, only a few criteria were cited, such as technical information and non-contractual information (e.g. *method statement*, *plant proposed* and *temporary works*). Findings of Holt *et al.* (1995a) demonstrate similarity with the Merna and Smith (*ibid.*) investigation. Holt *et al.*, (1995a) proposed three crucial stages of the selection process i.e. Stage 1 - *prequalification* (P1); Stage 2 - *tender evaluation* (P2); and Stage 3 - *final selection* (P3). P2 investigates more project-specific contractors' attributes, namely: *geographic experience; similar work experience; key persons available for the proposed project; current workload; prior relationships with the client;* and *office location* (with respect to the proposed project).

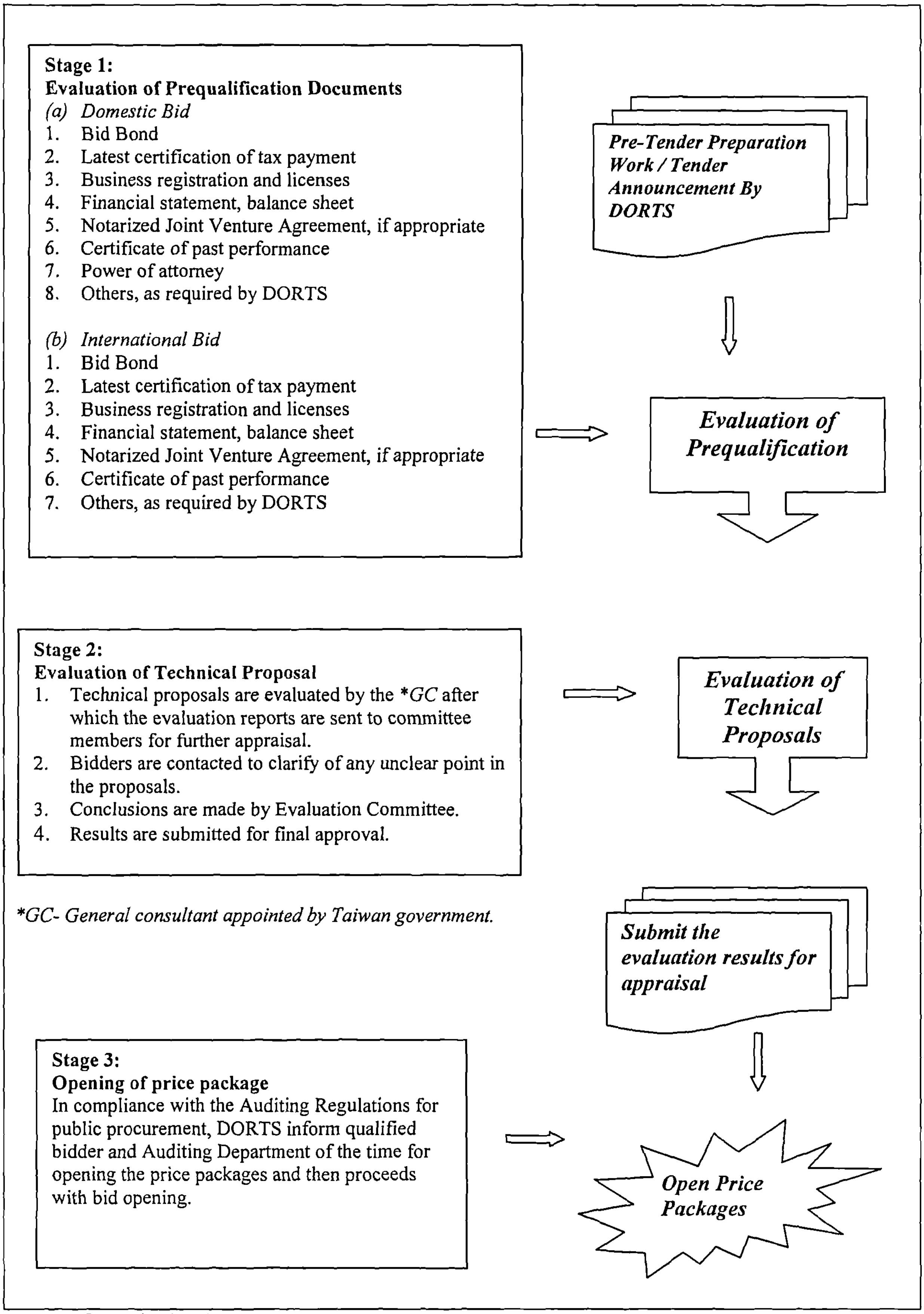
Guidance for competitive tendering has also been discussed by the Construction Industry Council (CIC, 1994). Greater emphasis was placed on 'value' assessment of tenderers rather than tender price (i.e. lowest tender). The CIC found that quality tempered by price will be the best option. Emphasis on 'value' was also discussed in the guidance document 'Code of Practice for Selection of Main Contractors' (CIB. 1997c). The Construction Industry Board (CIB) suggested that evaluation should be based on quality and price, and that tenders must offer best value for money.

A case study of the Mass Rapid Transit System (MRTS) construction in Taipei, Taiwan, charts a unique contractor selection process (Lo *et al.*, 1998). Unlike other major civil engineering contracts, the process takes account of gaining expertise and experience from advanced countries, to enhance domestic contractors' capabilities; achieve delivery of the project as a quality product and on time, and foster growth of domestic contractors and long-term economic developments. Despite orthodox selection procedures, MRTS allowed relaxation of the prequalification process for domestic contractors to encourage national participation. Nevertheless, the Department of Rapid Transit Systems (DORTS) introduced a structured approach for contractor evaluation. This three stage evaluation method consisted of: contractor *prequalification* (Stage 1); *evaluation of technical proposals* (Stage 2); and *finally invitation to all qualified tenderers* (after the Stages 1 and 2) for opening the price package proposed by each individual tenderer. Figure 3.2 shows the three-stage bid contractor selection and evaluation process used for the MRTS project.

Helmer and Taylor (1977), Bent (1984) and Birrell (1988) all advocated contractor management and project execution capabilities as vitally important. Helmer and Taylor viewed three major functional areas i.e. *planning, organising,* and *controlling.* They recognised that good management practices are responsible for contract success or failure. According to Bent, evaluation of contractor PSC should consist of *technical, project execution* and *contractors' contract / legal understanding* and *capabilities.* Birrell described a system, to evaluate contractors' past performance, by observing contractors' *general information, site management, resource flow* and *productivity management*, *cost* and *time management,* and *interface of the contractor with others.*

In an attempt at quantifying the contractors' managerial, technical, financial terms aspects of performance, Samelson and Levitt (1982) focused on selection of a 'safe' contractor. Indeed, health and safety awareness has become much focused in the UK construction industry since the advent of the Construction Design and Management Regulations (Joyce 1994). According to the latest survey, issues of health and safety performance have a much stronger influence on the selection decision in the UK public sector works (Wong *et al.*, 2001b).

Figure 3. 2: Three-Stage Contractor Selection Process for MRTS Projects



Source: Lo et al., (1998)

The promotion of health and safety in construction has been discussed in the Latham report (1994) and been the subject of campaigns and guidance from construction professional bodies (e.g. CIB, 1997c; CIOB, 2000;2001). Hence, it is not surprising that health and safety has taken on a more important role and become emphasised in other evaluation criteria.

Bastidas (1984) concentrated specifically on public bidding in the Mexican construction industry. A *technical-economic analysis* to *revise, analyse* and *compare* all components of bids was proposed. It was contended that the (Mexican) government office first select from a main register of contractors from the Ministry of Programming of Expenditure of Federal Government. Each register has contractors assigned into different divisions according to: *legal; financial; economic; technical; speciality;* and *experience* attributes. The list is very similar to the UK public works *initial list* used for prequalification purposes (Merna and Smith, 1990). According to Bastidas, potential bidders should be selected with respect to: *project type; size of job; financial capacity; technical capacity; technical personnel; construction equipment availability; specific experience;* and *job location.*

Having presented and critically discussed the literature, a summary of the findings is now presented.

3.2.1 Summary of Tender Evaluation Criteria from Literature Review

Contractor evaluation methodologies vary significantly. However, PSC have largely remain unchanged since 1980 (e.g. ICE, 1980). This can be seen from the common consensus in PSC, particularly with respect to contractors' *financial, managerial,* *technical, health* and *safety, quality*, and *past performance* aspects. These 'core' criteria were also common to: Helmer and Taylor (1977); Sameson and Raymond (1982); Moore (1985a;1985b); Holt *et al.*, (1994a); and Hatush and Skitmore (1997b). The majority of these commentators incorporated these criteria into their alternative contractor evaluation methods.

Nevertheless, PSC are ultimately associated with the 'lowest-price' criterion for final evaluation process. Findings from Hunt *et al.* (1966); Baker and Orsaah (1985); and Merna and Smith (1990) indicated that the 'lowest-price' principle still dominated clients' final choice of selection, particularly, in public sector works. Being aware of this, the lowest price principle survey in Chapter 6 investigates the impact and importance attached to PSC and the 'lowest-price wins' principle, among UK contractor evaluation and selection practices. From the literature review, nine main PSC categories were identified. These categories are:

i. manpower resources;
ii. equipment resources;
iii. project management capabilities;
iv. geographical familiarities;
v. location of home office;
vi. contractor's capacity;
vii. project execution of the proposed project;
viii. technical-economic analysis; and
ix. other relevant PSC (for particular types of work).

Details of the 37 PSC attributed to these nine categories are listed in Table 3.3. These criteria will then be used in the main (second) industry-wide survey and for case studies purposes (i.e. for developing contractor classification models).

Table 3. 4: The 37 Tender Evaluation Criteria

1. Manpower Resources	
	Quality and quantity of human resources
	Quality and quantity of managerial staff
	Amount of decision-making authority on site
	Amount of key personnel for the project
2. Equipment Resources	
	Type of plant and equipment available
	Size of equipment available
	Condition and availability equipment
	Suitability of the equipment
3. Project Management Capabilities	
	Number of professional personnel available
	Type of project control and monitoring procedures
	Availability of project management software
	Cost control and reporting systems
	Ability to deal with unanticipated problems
4. Geographical Familiarities	
	Contractor's familiarity with weather conditions
	Contractor's familiarity with local labour
	Contractor's familiarity with local suppliers
	Contractor's familiarity with the geographic area
	Contractors' relationship with Local Authority
5. Location of Home Office	
	Home office location relative to job site location
	Communication and transportation- office to job site
6. Capacity	
	Current workload
	Maximum resource/financial capacity
	Finance arrangements
7. Project Execution to the Proposed Project	
	Training or skill level of craftsmen
	Productivity improvement procedures and awareness
	Site organisation, rules and policies (Health and Safety etc.)
	Engineering co-ordination
8. Technical-economic Analysis	
	Comparison of client's estimate with tender price
	Comparison between proposal and average tender prices
	Comparison of client's and proposed direct cost
	Contractor's errors- proposed construction method/procedure
	Proposals review- unit price/labour cost/time/resources schedule
9. Other relevant PSC (for particular types of work).	
	Actual quality achieved in similar works to the proposed project.
	Experience with specific type of facility
	Proposed construction methods
	Ability to complete on time
	Actual schedule achieved on similar works

3.3 SUMMARY

Current contractor selection practice is beset with considerable shortcomings (Latham, 1994; Merna and Smith, 1990; Holt *et al.*, 1995a). Frequently, there is as over-reliance on the prequalification process, which in itself is deep-rooted with 'lowest-price wins' practice (*ibid.*). These shortcomings require the need for some revision of existing practice.

As long ago as the 1940's, contractor selection was given particular attention (e.g. Simon Committee, 1944). UK industry practitioners and commentators have subsequently and continually criticised existing selection practices (e.g. Banwell, 1964; Higgin, 1965; Mobbs, 1976; Latham, 1994).

Separate reports and studies of selection of a contractor have recommended a number of remedies to the shortcomings identified and offered a means of broadening the selection of a contractor, particularly, aimed at improving the efficiency of the construction process (*ibid.*).

The need for an objective approach in contractor selection is of vital importance. However, this must be considered in conjunction with a set of rationalised criteria, or a set of criteria that has the ability to mirror the project's requirements and the client's needs. The literature search has identified criteria for contractor prequalification and tender evaluation (i.e. PC and PSC). These observations will help design the surveys described in Chapters 4 and 5 and subsequently the development of a contractor classification model in Chapters 8 and 9.

CHAPTER 4

CONTRACTOR PREQUALIFICATION: AN INITIAL SURVEY OF UK PRACTICE

4.0 INTRODUCTION

Chapter Three provided an overview of the prequalification process and prequalification criteria, underlining the root of contractor selection processes and defining which selection methods and criteria to apply when making selection decisions. This chapter discusses the research methodology employed and the initial survey of UK prequalification practices (via interviews and follow-up questionnaire surveys) among a range of experienced practitioners. Parametric and non-parametric statistical analyses were applied to the survey data. The results show that there is a divergence of opinions pertaining to the use of contractor prequalification practices.

4.1 CONTRACTOR PREQUALIFICATION PROCESSES

In general, most projects have three key goals; to deliver the project on schedule, within budget and to specified quality (Bennett and Hanagan, 1983; Hewitt, 1985; Belassi and Tukel, 1996; Chinyio, *et al.*, 1998). To enhance the probability that these goals will be satisfied, commentators agree that a structured, quantifiable prequalifying procedure is needed (Hunt *et al.*, 1966; Hardy *et al.*, 1981; Russell and Skibniewski, 1987; Ng and Skitmore, 1993; Potter and Sanvido, 1994). In this respect, prequalification criteria (PC) have been extensively investigated by many (e.g. Russell and Skibniewski, 1988; Merna and Smith, 1990; Liston, 1994; Assaf and Osama, 1994; Holt *et al.*, 1994a; Bubshait, 1996; Hatush and Skitmore, 1997b; Ng *et al.*, 1999).

According to Russell and Skibniewski (1987) prequalification is a screening process. It investigates and assesses the abilities of a contractor. In order to become qualified, contractors should have basic competence and capabilities in managerial, technical and financial terms (Hunt *et al.*, 1966). Prequalification consists of evaluating the available pool of potential tenderers; who are (broadly) at this stage considered competent to carry out the work (*ibid*). Bent's (1984) view is that physical damages and financial loss to construction works can be reduced if prequalification includes assessment of contractors' managerial and project execution capabilities. Russell and Skibniewski (1987) point out that a fundamental function of prequalification is close scrutiny of contractors' abilities.

It has been shown that tender costs represent approximately 35% of contractors' turnover in the Australian construction industry (Liston, 1994). Jennings and Holt (1998) found that only 18.5% of tenders prepared and submitted by contractors each year in England and Wales were successful. To consider this another way, more than 80% of the cost of preparing tenders is 'wasted'. Inevitably, this cost of tender preparation is passed on to (i.e. recovered from) construction clients. Such problematic issues make efficient prequalification practice more than simply idealistic; effective and efficient practice can reduce clients' prequalification (e.g. administration) burden as well as save contractors' resources, during the tendering process. Other benefits of efficient prequalification include reduction of unnecessary cost and time for tendering (Russell and Skibniewski, 1987), and the encouragement of *suitable contractors* to tender (Kumaraswamy, 1996). Conversely, and of equal importance, the latter discourages unsuitable contractors.

Over the last two decades, numerous commentators have underlined the need for rigorous prequalification and selection procedure (e.g. Moore, 1985a;1985b; Merna and Smith, 1990; Holt *et al.*, 1995b; Hatush 1996). Professional bodies and industrial practitioners have also contributed to these assertions (e.g. IOB, 1979; ICE, 1980; NJCC, 1985;1991;1994a;1994b). Prequalification guidance and advice on selection procedures have resulted, these works having been explored by: Herbsman and Ellis (1992); Russell and Skibniewski (1988); Ng and Skitmore (1995); Potter and Sanvido (1994); and Liston (1994). However, the contractor prequalification process still exhibits much variance, for example, by use of numerous evaluation methods. It is also inherently subjective relying often on practitioners' experience, and a degree of 'good luck'.

At this point in the research, it is the attempt of this chapter to discover the merits and shortcomings of UK contractor prequalification first-hand; as perceived by selection practitioners. Particularly with respect to the current use of standard prequalification lists and other contractor standing / approved lists. Comparative analyses are made among the questionnaire survey data. The objectives of this (initial) survey may be defined as follows:

i. to investigate current usage of prequalification list(s), preferred contractor prequalification practice(s);

ii. to identify the common problems / deficiencies of the various prequalification lists, practices and criteria within the UK construction industry; and

iii. to look for 'common' criteria used in the prequalification process.

Following data analysis, and based on the research findings, conclusions are drawn at the end of this chapter in respect of these objectives.

4.2 PREQUALIFICATION: BACKGROUND

There are different prequalification methods used in the UK construction industry, particularly, among major public sector civil engineering works. Most public clients implement a variety of selection and evaluation methods (Merna and Smith, 1990). According to Merna and Smith, many of these conform to 'general' guidelines; acceptance of a contractor's proposal relies on successful prequalification and subsequent lowest priced tender. They also found that non-contractual information (e.g. method statements, plant proposed and temporary works) were often used to 'narrow down' an original large number of tenderers. These findings were also discussed in Holt *et al.*'s (1995a) investigation which identified four main deficiencies of UK selection practice:

i. lack of a universal approach to contractor selection;

ii. long term confidence attributed to the results of prequalification;

iii. dependency on tender sum (i.e. lowest tender) as the 'final' selection parameter; and

iv. an over-reliance on subjective analysis (i.e. bespoke methods, ad-hoc measures).

Latham (1994) discussed 'qualification' and 'prequalification' systems in some details and further advocated that qualification systems should be standardised (Chapter 2); it was urged that the government maintain a single and central UK qualification system. The abundant use of numerous *in-house* systems and *standing lists* was particularly condemned by Latham.

Since the Private Finance Initiative (PFI) scheme was launched in November 1992, a series of guidance documents (in this respect) have been published. Guidance for the Private Finance Initiative (PFI) procurement process was revised and published in April 1998 by the Treasury Taskforce, Private Finance Projects Team (Treasury Taskforce, 1999). According to this guidance, clients should assess suitable contractors (during prequalification) with evaluation based on the grounds of ability and commitment to offer a viable and realistic bid for the works intended.

Hatush (1996) classified two basic types of tendering procedure in the UK. The first was termed *Standing List Tendering Procedure* where bids are invited from a standing list (or register of approved contractors). The second was defined as *Project List Tendering Procedure*, where potential contractors are invited to tender (from an open / select list) for a specific contract. The standing list is similar to a list of qualified contractors. Hatush (*ibid.*) described *prequalification* as a process where contractors will be assessed on the grounds of their managerial and financial capabilities, technical expertise, and past performance criteria.

In Northern America, the merits and shortcomings of contractor prequalification have been discussed for several decades (Hunt *et al.*, 1966; Lewis, 1981; Martinelli 1986; Russell and Skibniewski 1987). Hunt *et al.* (*op. cit.*) stated that the need for a qualification system in civil engineering works is essential because it improves contract award practices. Russell and Skibniewski (1987) recommended that prequalification procedures should start with a draft list of potential bidders from a published register of contractors. These procedures should consider contractors' *financial, equipment resources, experience, size, previous performance* and *other information* considered relevant to the project requirements.

Having broadly discussed contractor prequalification processes and some experts' opinions on such, the following sections discuss the empirical findings of current UK prequalification practices (via an initial survey).

For brevity and to distinguish terms used in the following discussion, the terms 'contractor standing list', 'approved list' or 'project list' are all hereafter referred to as an *in-house* list. Other 'ad-hoc' or self-administered contractor lists are also hereafter cited as *in-house* lists. The term *standard list* refers to Latham's recommendation i.e. National Qualification System (NQS). That is, the merger of former ConReg and CMIS lists (Chapter 2). The term 'standard practices' means all activities confined to the prequalification process including use of a standard (prequalification) list, and recommended guidance and procedures.

4.3 RESEARCH METHODOLOGY

This section discusses the research methodology employed for investigating current contractor prequalification practices in the UK construction industry. However, the principles of this approach apply **equally** to the data collection exercises in Chapters 5 and 8.

The research methodology employed is characterised by the hallmarks of scientific research as discussed by Sekaran (1992:p10-14) including: *purposiveness; rigor; testability; replicability; precision and confidence; objectivity; generalisability;* and *parsimony*. The following section discusses how these were implemented into the study.

Purposiveness is defined as a definite aim or purpose of the research (Sekaran, 1992;p10-14). The main aim of this research was to develop a contractor classification framework achieved through successful implementation of the research objectives.

Rigor connotes carefulness, a good theory-based and sound research method design (*ibid.*). Yin (1984:p21) described how lack of rigor caused equivocal evidence or biased views to influence research outcomes. In the research, data was collected from both theory (i.e. literature review) and the practical experience of construction clients via a quantitative research method (i.e. structured questionnaire surveys and case studies). Data obtained was analysed via:

i. descriptive analysis of construction clients' prequalification opinions (parametric and non-parametric in Chapter 4, initial survey);
ii. quantitative analysis of construction clients' contractor prequalification and tender evaluation opinions (multivariate statistical analyses i.e. One-way / Two-way Analysis of Variances and post-hoc multiple comparison analysis in Chapters 5 and 6); and
iii. multivariate discriminant analysis (case studies in Chapters 8 and 9).

Testability is concerned with the validation of the findings. Data collected was analysed and tested using quantitative statistical techniques (i.e. SPSS computer programme). The developed models were validated using independent data and were found to be statistically robust.

Replicability demands that the results of the research should be supported when the research is repeated in other similar circumstances (Sekaran, 1992;p10-14). Here, data collection involved the nation-wide survey of construction clients and practitioners and the resultant models were found to be statistically robust. Albeit the nature of this research may be partly time-dependent, the replicability of the research was achieved through careful design and implementation.

Precision and confidence is concerned with how close to the 'truth' are the findings and the probability of the estimated results being correct (*ibid.*). To help achieve this, a high level of confidence (i.e. p value set at 95% confidence level) was employed during the analyses. That is, the results can be assumed to be correct with a high level of confidence.

Objectivity is connoted with the interpretation of the results from research data should be objective. The conclusion drawn from the empirical data must not be biased, subjective opinions or emotional values (*ibid.*, p13). It is contented that the more objective the interpretation of the research data; the more scientific the research becomes.

Generalisability refers to the applicability of research findings to a wider range of people or organisations (*ibid.*). This issue relates to the research sampling design. A more elaborate sampling would increase the generalisability of the results but inevitably increase resource implications of the research. In view of time and resource limitation for this research programme, investigation of the entire population is impossible. However, attempts were made to sample a diverse cross-section of construction clients and practitioners (i.e. different backgrounds and geographical area) for the research, including public clients and clients' representatives.

Parsimony pertains to the simplicity of the research framework. The aim here was to avoid development of an elaborate and cumbersome model for the solution of the research aim. Beside, the fewer number of variables would explain the variance far more efficiently than a complex set of variables (*ibid.*). In the context of this research, the variables (PS and PSC) were derived from a detailed literature (Chapter 3) and initial survey. The same variables (i.e. PC and PSC) were used for both building and civil engineering works to investigate the extent of client's preference (LIA) in each variable (Chapters 5 and 6). These variables (PSC) were carefully selected for the subsequent case study survey for developing contractor classification models (Chapters 8 and 9). Therefore these variables were used consistently through out the investigation. Further, the post-hoc multiple comparison procedure and MDA technique have successfully derived a set of most 'parsimonious' PSC (i.e. statistically significant different among the surveyed respondents) regarding LIA for selecting good performance contractors (Chapters 6, 8 and 9).

4.3.1 Choice of Sampling Survey

It is impossible to survey all construction practitioners (e.g. clients, consultants, engineers, project managers, contract managers, quantity surveyors, contractors, etc) as this would be impractical and extremely expensive. According to Nachimias and Nachimias (1996:p179) *generalisation* in empirical survey is usually based on partial information from the entire population. As there was no deliberate attempt to sample a particular group of organisations, the research sampling was based on 'willingness' and of the 'right' practitioners to participate. Therefore, in this regard practitioners from different backgrounds with **experience** in the contractor selection process and **willingness** to participate were invited. This type of sampling has been cited as a 'convenience sample' (i.e. a non-probability sample design) due to the reasons of convenience and economy (*ibid.*, p184). This method has been advocated by many in construction research (e.g. Holt, 1995; Kometa; 1995; Hatush, 1996; Kaming, 1996; Chinyio, 1999; Nichola, 2000), particularly, when a sampling population cannot be precisely defined and / or list of the construction sampling population is unavailable.

However, attempt has been made to compile the groups of samples as representative as possible from the construction industry populations. This endeavour was achieved by targeting a number of 'predominant' subsets from the lists of: the largest public sectors clients lists; recommended professional bodies; and the most widely used British enterprises directories. To access these samples the following sources were used:

i. Housing Associations and Directory Yearbook (NFHA, 1998);
ii. Municipal Year Book and Public Service Directory (Yorke, 1998;2000);
iii. Key British Enterprises (Dun & Bradstreet, 1998;2000);
iv. Association of Project Management Yearbook (APM, 1998);
v. The Property Profession Chartered Surveyor Regional Directory (RICS, 1997);
vi. Chartered Building Company Directory and Handbook (CIOB, 1998); and
vii. Construction Industry Compendium 2000 (Clayfield and Smart, 2000).

This chapter present details of the initial survey undertaken to identify existing prequalification procedures used by construction clients in selecting appropriate contractors prior to the invitation to tender.

4.3.2 Data Collection Method

Most of the research in construction management involves opinions survey via mailed questionnaires and may be considered exploratory or symbolic in nature (Holt and Faniran, 2000). Very often, such research is conducted in a limited time-scale and with limited resources and aims to achieve knowledge advancement (springboard) for future research (*ibid.*). In construction management research, surveys can be conducted using questionnaires, interviews and case studies to obtain 'hard data' such as project cost and 'soft data' for example clients' perceptions regarding contractor performance (Liu and Fellow, 1997:p89-95; Holt and Faniran, 2000). Other advantages of using postal questionnaire surveys include: low cost; quick response; accessibility (able to cover diverse locations); assurance of anonymity; and reduce biasing error (relationship with the respondents) have been highlighted by many (e.g. Hoinville and Jawell, 1978:p124; Sekaran, 1992:p201; Nachmias and Nachmias, 1996:p225). Having considered these advantages, a (postal) questionnaire survey method was used in the research for the initial survey, second survey and the 'case study'.

The design of these questionnaires was kept relatively simple and straightforward. In the initial survey, respondents were asked to assign and select the most important criteria for prequalification process. The scope of the initial survey questionnaire was limited to one page of A4 and consisted of 5 groups of questions (*refer* Appendix A for details):

i. sample classification data;

ii. type of prequalification lists used in past and present experiences;

iii. method(s) of investigation used to evaluate contractors during prequalification;

iv. prequalification criteria applied; and

v. perceived merits and demerits of a standard contractor list.

Likert scales were adopted in the second industry-wide survey and case study investigations where each respondent was requested to tick and select *levels of importance assigned* to each PC and PSC for selecting a 'good' contractor, based on their experience. Details of these surveys are presented and discussed separately in Chapters 5 and 8, respectively.

4.3.3 Analytical Survey Method

Holt (1998:p83) highlighted two distinct categories of survey methods in built environment research, namely *qualitative* and *quantitative* approaches. Holt (*ibid.*) described process observation, unstructured interview and open question survey as being synonymous with qualitative methods and, structured survey / interview, symbolic models and physical experimentations as quantitative methods. In the present research, observation of construction practitioners' opinions was quantified into an interval and ratio scale (via structured questionnaire surveys). Interval and ratio variable are highly recommended in quantitative research since they represent the highest level of measurement and hence produce rigorous statistical results (Bryman and Cramer, 1999:p58-60). The analysis of observed data was conducted using statistics in a quantitative approach. That is, a quantitative survey method and analytical approach were chosen for the research.

4.4 INITIAL SURVEY

The initial survey was designed to collect information regarding current contractor prequalification practices in the UK and detailed investigation of:

i. type of prequalification lists used;

ii. methods of investigating contractors during prequalification;

iii. contractor prequalification criteria applied; and

iv. the extent to which a central 'standard' list is used, and why.

The questionnaire design was based on the literature review and complimented with information collected from telephone conversations (i.e. interviews) with experienced selection practitioners in a semi-structured manner. The interviews allowed observation of current industry prequalification practices and helped to improve the (initial survey) questionnaire design. Participants in these interviews included public clients, clients' representatives and contractors. Further details of these participants are presented in Section 4.4.1. Following this, a structured questionnaire survey was then conducted among UK construction industry clients.

In the questionnaire survey, respondents were invited to give their perceptions with regard to *prequalification practices*, use of *prequalification criteria* when selecting contractors, and also *comments* toward the use of a central UK, single prequalification list (i.e. NQS).

4.4.1 Interviews with Construction Practitioners

This aspect of the investigation commenced with semi-structured telephone interviews. The interviewees were carefully selected to target participants with relevant prequalification experience using a 'convenience sample' survey manner. The interviewees comprised six public clients selected from the Municipal Year Book and Public Service Directory (Yorke, 1998); three clients' representatives from The Property Profession Chartered Surveyor Regional Directory (RICS, 1997) and the Association of Project Management Year Book (APM, 1998); and three contractors selected from the Chartered Building Company Directory and Handbook (CIOB, 1998).

In addition to possessing relevant experience, the selection process aimed to encompass:

i. a diverse range of business;
ii. companies with a minimum turnover £ 1 million; and
iii. companies that were actively involved in the construction process (procurement) over the past three years.

The main consideration during sample compilation was to encompass organisations from a diverse range of backgrounds (i.e. nature of business), experienced and competent (i.e. company size and turnover), and to have been active within the industry. This was achieved by selecting organisations from the lists of construction professional bodies (e.g. Chartered Surveyors Regional Directory). By virtue of their professional (*Chartered*) status, these companies would have successfully passed external audit (e.g. through staff competency, organisation performance and annual turn over). The list of interviewees comprises practitioners from various organisations representing a variety of different businesses including: local authorities; consultant firms; contracting firms; contractors; engineers; project managers; consultant quantity surveyors and builders.

As interviews are highly labour intensive and time-consuming only a limited number were undertaken. The purpose and objectives of the interviews were explained to the interviewees via: (1) sending a list of the interview questions; and (2) an informal telephone conversation prior to the actual interview taking place. The list of questions covered the main issues identified in the literature review (and the objectives of the research). The interviewees were asked:

i. *type* of prequalification list(s) used;
ii. *methods* for contractor scrutiny when prequalifying;
iii. *prequalification criteria;* and
iv. *merits / deficiencies* of a standard list.

The results of this preliminary investigation were very useful and provided input to the subsequent (initial) questionnaire design (presented later in this chapter).

Twelve of the interviewees (80%) agreed that a wide diversity of prequalification lists were used in their past and present experience. These interviewees preferred their own *in-house* lists despite easy access to a standard list. Lack of 'flexibility' was cited as the main barrier in this respect. The general consensus of opinion on this was that a standard list covered too many contractors and increased resource implications. Furthermore, a standard list does not consider project-specific criteria and clients' individual preferences. Such indications are important, because the reasons given for non-use of a standard list contradict those cited (i.e. by Latham) for establishing such a list in the first place (Chapter 2)

In some circumstances a standard list cannot cope with the specific aspects of a project, such as project functional requirements, locality or remote location. Some of the interviewees revealed that they prefer partnering arrangements instead of the 'traditional' prequalification approach, mainly because they could have 'immediate' contact with contractors (particularly with whom they have prior working relationships). In other words, it was generally perceived that prior relationships or partnering saves time, cost and administration. Some interviewees preferred to have three to six tenderers for a project, where they picked from a 'pool' of contractors available on a routine basis. Overall, it is reasonable to suggest that, the interviewees preferred partnering and close working relationships rather than traditional contract-based, competitive selection practices. Such indications are in line with earlier findings (Holt and Fraser, 1999).

The interviews with contractors revealed that to be included on a prequalification list, they were often asked by clients to submit different types of 'prequalification' forms. Public clients tend to insist on their own prequalification list instead of using a standard list. Different public clients use different types of prequalification forms to obtain contractors' information.

One of the interviewees confirmed that a special 'work force' had been set up (within their company) in response to the increased use of different prequalification regimes. It was believed that, by adopting this approach they could achieve a 'good' submission when invited to prequalify. Interviewees also indicated that a good prior-working relationship normally meant a 'good' interface with clients. They believed that such a relationship gave positive impact on being maintained on an approved list or project-tendering list. This subsequently made them feel 'optimistic' and positive about being invited to tender.

4.4.2 Initial Questionnaire Survey

In the initial questionnaire survey, 434 construction clients from the UK were selected from:

i. Association of Project Management Year Book (APM, 1998);
ii. Housing Associations and Directory Yearbook (NFHA, 1998);
iii. Municipal Year Book and Public Service Directory (Yorke, 1998); and
iv. The Property Profession Chartered Surveyor Regional Directory (RICS, 1997).

The sample selection criteria were as follows:

i. a geographical spread of construction clients from across the UK (e.g. England, Northern Ireland, Scotland and Wales);

ii. companies of a professional or chartered status (e.g. Royal Institution of Chartered Surveyors and Association of Project Management);

iii. a range of project types: building and civil engineering works including; maintenance, refurbishment and new construction; and

iv. key personnel involved in contractor selection experience over the past three years.

Table 4.1 shows the distribution and response to the survey. A total of 238 public clients and 196 clients' representatives were targeted; 39 (16%) and 30 (16%) completed questionnaires were returned respectively. Table 4.2 shows the geographical spread of respondents.

Table 4. 1: Initial Survey and Response

	No. Sent	*Returned Completed*
Public Clients		
Housing Associations and Directory Yearbook (NFHA, 1998)		
Municipal Year Book and Public Service Directory (Yorke, 1998)	238	39
Clients' Representatives		
Association of Project Management Year Book (APM, 1998);		
The Property Profession Chartered Surveyor Regional Directory (RICS, 1997)	196	30
Totals:	*434(100%)*	*69(16%)*

Table 4. 2: Regional Classification: Public Client and Client's Representative

	England	Scotland	Wales	N. Ireland	Totals
No.	32	18	11	8	69
Percentage	47	26	16	11	100

4.4.3 Analysis of Survey Data

Parametric and non-parametric tests were applied to the survey data i.e. the One-way Analysis of Variance (ANOVA) and Spearman Rank Correlation Coefficient (SRCC) tests. Both methods have been widely used in construction research, to investigate significant difference between and correlation of data sets (e.g. Proverbs *et al.*, 1998;1999; Wong *et al.*, 1999;2000a;2000b;2000c;2001a;2001b). ANOVA evaluates between-groups variability against within-groups variability to compute whether a significant difference exists between the means of samples (Holt, 1998b:p108). Therefore, in this analysis the ANOVA tests were used to determine the significant *differences* (in means) between the contract value and types of prequalification list used as reported by the respondents. SRCC was used to investigate association of the extent of prequalification usage between public clients and clients' representatives.

There were 39 (16%) questionnaires returned completed from public clients (i.e. local authorities and other government agencies), and 30 (16%) from clients' representatives (i.e. their representatives and consultants). Given a total response of 69 (16%), this was considered valid for rigorous analysis (Harper, 1971:p21). According to Bailey (1982:p96) and Champion (1970:p89) 30 cases is the bare minimum, if statistical analyses are to be applied. In built environment research, Holt (1998:p94) suggests that minimum samples size should be confined to 30 if significant statistical results are to be yielded. Therefore, the total number of respondents obtained in this initial survey is adequate for conducting a robust statistical analysis.

Initially, usage of *standard* lists (e.g. NQS and European Union [EU] Works Directives- *Official Journal of the European Communities* [OJEC]) and *in-house* lists were investigated. Table 4.3 shows a comparison of the total number and value of projects assigned in different prequalification lists as reported by respondents.

Table 4. 3: Use of Prequalification List

	Number of projects.	Contract sum (£ million)	Mean contract sum (£ million / project)
Public			
NQS	6 (1%)	5.4	0.9
EU Directives- OJEC	25 (3%)	85.5	3.42
In-house list	658 (96%)	184.9	0.28
	689 (100%)		
Clients' representatives			
NQS	0	0	0
EU Directives- OJEC	127 (17%)	269.9	2.13
In-house list	599 (83%)	802.5	1.34
	726 (100%)		
Public			
Standard list (NQS & OJEC)	31	90.9	2.93
Combined (Public & clients' representatives)			
Standard list (NQS & OJEC)	158	360.8	2.28
In-house list	1257	987.4	0.79

Results show that 89% (1257/1415) of the total number of projects (658 number in the public sector and 599 number in the clients' representatives combined) were awarded from *in-house* lists. The others, 31 projects from public clients and 127 projects from clients' representatives, used the NQS and / or EU directives (i.e. OJEC). However, in terms of the average contract value per project, the figures equate to £0.28 million for pubic clients and £1.34 million for clients' representatives using own *in-house* contractor list, whilst of those using standard lists (NQS and

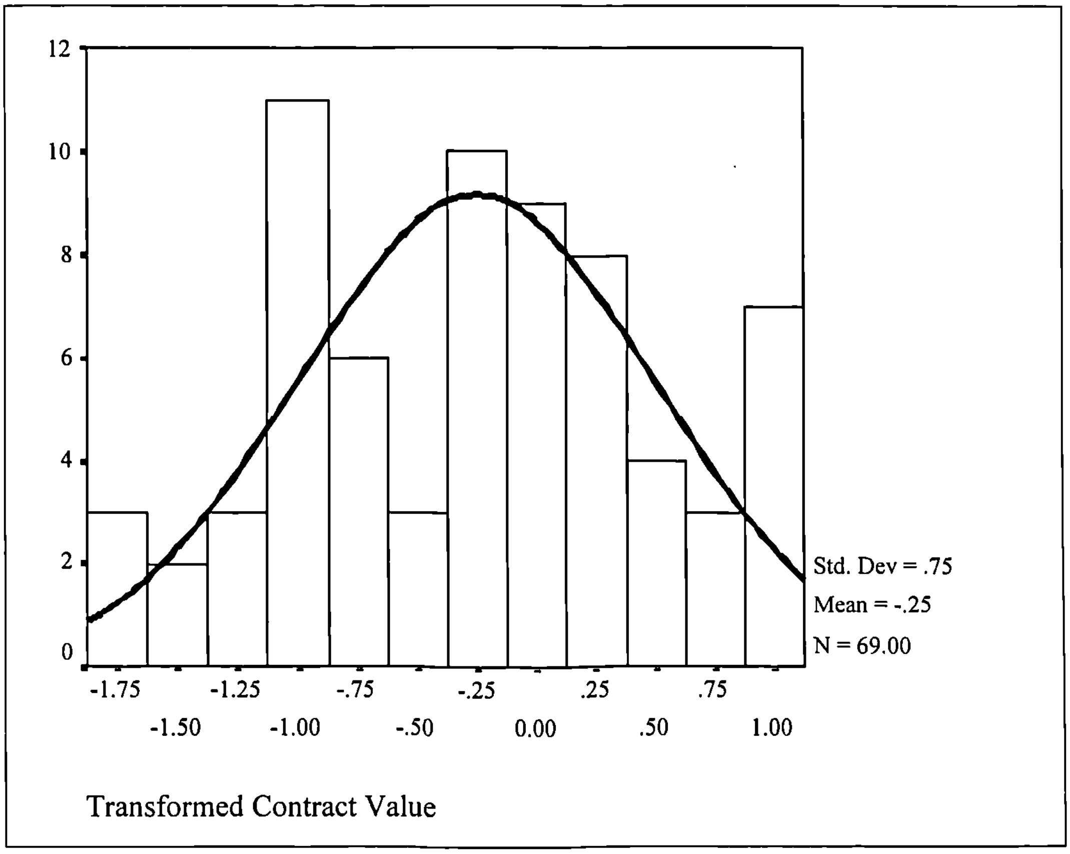
OJEC combined) the averages are £2.93 millions and £2.13 millions respectively. The foregoing also confirms that 89% of the projects with smaller contract sums (£0.79 million per project) were awarded using in-house lists, whilst the remaining 11% (average of £2.28 million per project) used standard lists. It seems that the *in-house* contractor lists are favoured for smaller contracts.

4.4.3.1 ANOVA Test

The ANOVA is a parametric procedure. Therefore, assumptions of: (1) independent samples; (2) normal distribution of samples; and (3) constant variances between samples are required. The independence assumption means that the samples have no relationship between observations in the different groups and between observations in the same group. For this survey, the samples were carefully selected and each participant supplied detailed information based on individual experiences. For example, each of the respondents (public clients / clients' representatives) was asked to give opinions regarding use of standard prequalification list (or contractor lists) based on their own experience. Thus, each observation has no relationship within the same group or between the different groups (public clients and clients' representatives). Therefore, the independence assumption is well conditioned.

The normality assumption can be determined by forming a histogram or normal probability plot. Figure 4.1 shows a histogram of the (log transformed) data distribution; it can be seen that the distribution is slightly positively skewed.

Figure 4. 1: Normal Distribution Plot



However, according to Norisus (1995:p283), in practice the analysis of variance is not heavily dependent on the normality assumption as long as the data are not extremely non-normal. Perfect normal distributions are rarely found in reality and therefore most statistical scientists presume that the variables being analysed are normally distributed (Bryman and Cramer, 1999:p93). Therefore it can be assumed that the distribution of data in Figure 4.1 is approximately normal and comes from a normal population.

The assumption of equal (constant) variance can be checked by the *Levene test*. The *Levene test* is an homogeneity of variance test, being less dependent on the assumption of normality than most tests and is particularly useful for analysis of variance (Norusis, 1995:p261). The null-hypothesis for this test is that two samples come from populations with the same variances. Since the observed significance level from the test is 0.231 ($p > 0.05$, Table 4.4), this means that the equal variance hypothesis cannot be rejected (i.e. constant variances between the samples). Therefore, the assumption that all samples come from different populations with equal variances is proven. Detailed explanations of the procedure's assumptions can be obtained from Norisus (1995:p283).

Table 4. 4: The Levene's Test

Contract value (*Log* transformed)			
Levene Statistic	df1	df2	Sig.
1.464	1	67	*.231*

Note: Levene statistic is used for equal variance test, result shows that there is no significant difference (p value of Levene's test = 0.231) between the variances of the groups.

Based on these primary statistical tests, the parametric assumptions are valid for this analysis. One-way ANOVA was used to determine whether the mean of contract value is significantly different between the *in-house* and *standard* lists among the samples. The following hypothesis was tested: H_o = '*mean contract values are equal*'; H_1 = '*mean contract values are unequal*'. Results presented in Table 4.5 reveal that contract value is statistically significant (i.e. $p<0.0005$) for the two *alternative* prequalification lists. In other words, there is a significant difference in contract value for projects using standard lists and in-house lists.

Table 4. 5: One-way ANOVA Test

Contract value (dependent) and prequalification lists (factor). Contract value (Log transformed)					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	12.978	1	12.978	34.628	*.000*
Within Groups	25.110	67	0.375		
Total	38.087	68			

Note: Result indicates that there are significant differences (p<0.0005) in the means of contract value in type of prequalification lists used.

4.4.3.2 EU Procurement Directives

In the case of contracts awarded in compliance with EU procurement directives, there were 152 projects with a total value of £355 million from both public clients and clients' representatives combined. This represents 26% (£355 million / £1348.2 million) of the total contract value or 11% (152/1425) of the total projects reported. These results show the growing significance of 'cross-border trade' in the single European market. Similarly, it can be suggested that impact of this will help encourage the use of a 'standard' and 'central' UK prequalification system for future 'official' contractor lists in EU procurement, particularly, for public contracts. Such awareness was highlighted in the Latham Report (1994) and by the CIB (1997a; 1997b).

4.4.3.3 Prequalification Investigation Methods

Table 4.6 shows the type of contractor investigation used by respondents. Public respondents tended to use an *enquiry letter / questionnaire* and *contacted referees / third parties* for contractor information.

Table 4. 6: Type of Investigation Methods Used during Prequalification

	Public		Clients' Representatives		Combined	
	No.	*%*	*No.*	*%*	*No.*	*%*
1. Enquiry letter/questionnaire	32	*31*	12	*19*	44	*25.1*
2. Contacting referees/third parties	29	*28*	11	*18*	*40*	*22.8*
3. Information from contractors' 'qualification'	21	*20*	16	*25*	*37*	*22.9*
4. Inviting contractor for an interview	11	*11*	16	*25*	*27*	*18.0*
5. Other methods	10	*10*	8	*13*	*18*	*11.2*
Totals:	103	*100*	63	*100*	*166*	*100*

Private respondents used a broader variety of methods. This indicates that public clients tend to follow more 'formal' investigation methods. One can reasonably assume that this is so as to offer some extent of public accountability and to exercise 'fair judgement'. Comments (i.e. 'Other Methods') from respondents also indicated that a 'direct approach' and 'independent review' are important and should always be emphasised. These include:

i. undertaking an independent financial review;

ii. informal discussion via fax / telephone;

iii. telephone enquiry to confirm expression of interest;

iv. site visit to projects in progress or recently completed;

v. evaluation of past experience / performance; and

vi. use of company quality evaluation forms.

It is worth noting that these reported approaches are very different, sometimes contrasting with standard practices. More obviously, they are subjective and rely on individual experience and judgement.

4.4.3.4 Prequalification Criteria

Ten prequalification criteria were adopted from the literature review (i.e. Russell *et al.,* 1992; Holt *et al.*, 1994a; and Hatush and Skitmore, 1997b). The survey questionnaire asked, *"Which are the most important prequalification criteria when compiling a prequalification list?"* Table 4.7 shows the overall ranks for prequalification criteria arranged in descending order of importance reported from public clients and clients' representatives respectively, based on the number of firms cited by the respondents. Both categories of clients have close consensus in this particular concern, as indicated by Spearman Rank Correlation Coefficient (0.71, *p*< *0.05*).

Table 4. 7: PC Ranked in Descending Order of Importance

	Public clients			**Clients' Representatives**			**Combined**		
	No.	*%*	*Rank*	*No.*	*%*	*Rank*	*No.*	*Ave. %*	*Rank*
1. Financial stability	34	*15.2*	1	18	*12.2*	2	52	*13.7*	*1*
2. Technical expertise	30	*13.4*	4	19	*12.9*	1	49	*13.2*	*2*
3. Past performance	33	*14.7*	2	16	*10.9*	6	49	*12.8*	*3*
4. Health and safety	31	*13.8*	3	17	*11.6*	4	48	*12.7*	*4*
5. Quality performance	28	*12.5*	5	18	*12.2*	2	46	*12.4*	*5*
6. Managerial capabilities	21	*9.4*	6	17	*11.6*	4	38	*10.5*	*6*
7. Company size / reputation	17	*7.6*	7	16	*10.9*	6	33	*9.2*	*7*
8. Claim / litigation history	17	*7.6*	7	10	*6.8*	9	27	*7.2*	*8*
9. Prior working relationship	8	*3.6*	9	12	*8.2*	8	20	*5.9*	*9*
10. Others	5	*2.2*	10	4	*2.7*	10	9	*2.4*	*10*
Totals:	224	*100*		147	*100*		371	*100*	

Note: Spearman Rank Correlation Coefficient, r_s *between Public and Private = 0.715. Correlation is significant at the 0.05 level (2-tailed)*

It was found that, *financial stability, technical expertise, past performance, health and safety,* and *quality performance* are perceived most important (ranked top 5) for a wide range of construction works. These findings provide a platform for initiating the comprehensive analysis of prequalification criteria in the following chapters. Broader elucidation of prequalification criteria (via second industry-wide survey) is discussed in Chapter 5.

4.4.3.5 Reasons for Non-use of Standard List

There appears no obvious reason why UK construction clients are reluctant to use a standard list (i.e. NQS). Thus, one of the objectives of the questionnaire survey was to investigate this. Six main reasons reported in the preliminary interviews survey were presented in the questionnaire. Table 4.8 shows that the majority of clients cited reasons for their reluctance in this respect. Surprisingly, 'Other Reasons' were the main causes of the unpopularity of a standard list. Some of the many reasons expressed are listed in Table 4.9. The findings suggest that most respondents preferred their own *in-house* lists rather than a *standard* list. By this, they feel that they can achieve wider 'flexibility' and 'tolerance' to meet their projects' needs. Other factors such as contractor *suitability* to the nature of the work, *project-specific requirements* and *resource implications* also dominated here.

Table 4. 8: Reasons Cited Clients are Reluctant to Use of the 'Standard' List

	Public		C's R.		Combined	
	No.	*%*	*No.*	*%*	*No.*	*%*
1. *Other reasons**	19	*28.8*	8	*18.2*	*27*	*23.5*
2. It does not take into account project-specific requirements	13	*19.7*	12	*27.3*	*25*	*23.5*
3. Covered too many contractors	14	*21.2*	8	*18.2*	*22*	*19.7*
4. Resource implication	8	*12.1*	5	*11.4*	*13*	*11.7*
5. Insignificant in particular area	6	*9.1*	6	*13.6*	*12*	*11.4*
6. Does not consider client's preferences	6	*9.1*	5	*11.4*	*11*	*10.2*
Totals:	66	*100*	44	*100*	*110*	*100*

*See *Table 4.9*

Table 4. 9: "Other Reasons"

Public clients
"It covered *too many* contractors in a *nation wide approach*"
"Too many *national large* contractors, which are not suitable for *small* and *one-off* projects."
"Does not include local contractors, who can *respond quickly* to the tendering process."
"Most of our contracts are relatively *small* and *local.*" "For small contracts, we *prefer* local contractors."
"It is not meaningful to the *specific area*, such as local authority *geographical area.*"
"It is the *council's policy* to form its own list of approved contractors."
"We would wish to gather our *own data* at the prequalification stage for the prequalification process."
"It is *not* for local contracts." "We would rather compile our *own* contractors list."
"We work on a *term maintenance contract*, we prefer to use our own system which is more suitable for *local contractors* even though we have National Sub-contractors on our list."
"Our council prefer to use contractors from the *local area* for the majority of projects."

Clients' Representatives:
"Many of our projects are *specific* and *unique*, and also in a *remote location.*"
"We are *not aware* of standard practices."
"It is *not meaningful* to the specific area, a majority of our clients are housing associations."
"We do consider *project-specific basis* only."
"It is *not suitable* for us, we run school, local housing repair and maintenance works."
"Our own '*National Contractors*' list is more closely related to our requirements."
"We have the tender list *compiled specifically* to specific projects."
"We tend to use *known package contractors* who have a prior relationship over the past few contracts."
"We insist on *our* approved list."
"Have *not* used these standard practices before."

4.5 DISCUSSION OF THE INITIAL SURVEY FINDINGS

Some of the factors cited by respondents indirectly highlight the need for a more 'project-specific' and 'flexible' standard list i.e. factors such as *consideration of small, unique projects; clients' preferences; location of projects;* and *project-specific requirements* (Tables 4.8 and 4.9).

The statistical tests show that there is significant difference between contract value and the use of contractor prequalification lists. Respondents tended to use in-house prequalification lists for smaller projects and standard lists for larger projects (i.e. £0.79 million per project and £2.28 million per project respectively). This could be attributed to the reasons cited as above i.e. more 'project-specific' and tailored to the project's needs and different types of workloads. The findings indicate that clients seem reluctant to adopt standard practice. To overcome these hurdles and to best serve users, the standard list needs to be 'revised' and should accommodate the highlighted, perceived constraints (Tables 4.8 and 4.9).

Findings from investigation of *contractor prequalification criteria* show that there is a 'common' set of prequalification criteria (i.e. *financial, technical, past performance, health and safety and quality performance*, Table 4.7), which are consistently used by practitioners during prequalification. A most notable aspect of these findings is that, such criteria have been perceived equally important by both public clients and clients' representatives (i.e. SRCC test r_s = 0.72). This suggests that divergence in use of prequalification practices does not exert influence on the application of prequalification criteria. Perhaps, it shows that most UK clients apply 'identical' contractor prequalification criteria in the prequalification process, despite each distinct prequalification setting. These common criteria were also noted in the findings of Holt *et al.* (1994a) and Hatush and Skitmore (1997b).

4.6 SUMMARY

According to the questionnaire survey, almost 89% of projects were awarded based upon 'self-developed' contractor databases and utilised clients' own experience and subjective judgement. This situation pertains despite increased urges for a 'single' and central UK prequalification system (Latham, 1994). It is also interesting to note that most clients show a substantial amount of confidence in their 'self-developed' prequalification practices in small projects (Table 4.3), which rely heavily on past experience, and individual knowledge of the particular works. Such confidence has inevitably encouraged the continuing application of *in-house* lists. On the other hand, respondents also highlighted factors that have a negative impact on their willingness to use national standard practices. These factors may be summarised as:

i. lack of flexibility;
ii. lack of tolerance to clients' specific requirements, such as consideration of clients' preferences, geographical / locality concerns, project-specific requirements; and
iii. long term confidence attributed to 'self-developed' database / contractor lists.

The survey revealed a divergence of opinions pertaining to the use of contractor prequalification lists. Most of the respondents advocate in-house (self-developed) databases and selection methods. Such fragmented practices bring both positive and negative effects to the industry. On the positive side, this provides flexibility, which allows construction clients to deal with variable workloads. On the negative side, it inhibits standard practice and broad dissemination of good practice for better performance.

However, in a broad sense, impetus to reinforce the use of a single and standard prequalification list is needed. Enhancement in this setting would allow construction clients to reduce their contractor selection burden as well as reduce contractors' resources during preparation to tender. In summary, much has evolved from this initial phase of the study. The reasons for non-use of standard prequalification lists and standard practice have been identified. This provides useful information for reviewing current prequalification practice and suggestions for future possible changes.

The survey revealed a consensus in perception of importance attached to contractor prequalification criteria. Both public clients and clients' representatives used the following five major criteria for prequalification: *financial stability; technical expertise; past performance; health and safety;* and *quality performance.* These main criteria were adopted in a wide range of construction works. Therefore, the following chapters will discuss a set of criteria associated with given types of projects and clients. These identified prequalification criteria and corresponding clients' preferences are further discussed in the next chapter.

CHAPTER 5

ANALYSIS OF CONTRACTOR PREQUALIFICATION CRITERIA

5.0 INTRODUCTION

The initial survey described in Chapter 4 concluded that a consensus exists among practitioners regarding perception of importance attached to five major criteria for prequalification. These five prequalification criteria (PC) are: (1) *financial stability;* (2) *technical expertise;* (3) *past performance;* (4) *health and safety;* and (5) *quality performance.* This chapter investigates a more comprehensive set of PC and performs an in-depth study of their extent of usage i.e. via *levels of importance assigned* (LIA) to these criteria by practitioners, for use in the prequalification process in building and civil engineering works. The investigation of PC was conducted through a second industry-wide survey. The findings show (using correlation tests) that the majority of respondents viewed LIA (for the particular PC) similarly. However, there were also significant differences of LIA among the respondents for certain PC, as reported by the *post-hoc multiple comparison* analysis results. The chapter comprises three main components. These are:

i. *questionnaire survey* i.e. design and method of survey;

ii. *statistical analyses* of survey data; and

iii. *discussion* of the findings of analysis.

5.1 THE EMPIRICAL SURVEY OBJECTIVES

The main aim of this chapter is to investigate a set of PC and its LIA reported by construction practitioners (i.e. via a structured questionnaire survey). The research presented also analyses relationships among PC identified from the survey, both *within* and *among* the respondent types and project characteristics. These analyses show significant differences in LIA among individual PC, used in building and civil engineering projects, and for given types of client. Similarities among groups of criteria were also discovered.

In view of subjectivity associated with types of PC used in the contractor selection process, a set of 'standard' PC (and PSC) was employed for both building and civil engineering works. This precaution was taken to avoid an excessive number of PC in statistical analyses (i.e. feedback and proposed additional PC from respondents).

5.2 QUESTIONNAIRE SURVEY

It was established by Rossi *et al.* (1983) that a questionnaire is essentially an instrument to enable communication between researcher(s) and respondents. Here, a structured postal questionnaire survey was used, to collect detailed information from a wide range of professionals involved in prequalification practices located across the UK. Detailed discussion of the choice of postal questionnaire survey has been highlighted in Section 4.3 (Chapter 4).

5.2.1 Questionnaire Design and Content

The questionnaire was developed based on information obtained from detailed literature review (Chapter 3) and findings of the previous initial survey (Chapter 4). The layout and format of the questionnaire was given particular attention to enhance the response rate and to meet the objectives of the research study. The questionnaire comprised three components: (1) *sample classification*; (2) *respondents' opinions* (i.e. LIA for PC, based upon their past three years' prequalification experiences); and (3) LIA for *project-specific criteria* (PSC) when evaluating tenderers. It is Components (1) and (2) that this chapter concentrates upon. Component (3) is discussed in Chapter 6.

Component (1) (*refer* Questions 1 to 3 in Appendices B1 and B2) served to enable data classification. Information was requested regarding types of respondents; geographical location of respondents; nature of respondents' business; and number / value of contracts completed in the past three years. A *Likert scale* (1 to 5) was used to measure respondents' opinions in Component (2) i.e. regarding LIA for each PC based on the completed contracts in their past three years' procurement experiences. The scale was: 1 equals *not important*; thorough to 5 representing *extremely important*.

A small pilot survey was undertaken involving ten construction practitioners (four were public clients and clients' representatives respectively; and two were contractors) in order to give some feedback on the design, layout and context of the questionnaire. Following this, a number of minor revisions were made to the grammar and format of the questionnaire. The clients' questionnaire and contractors questionnaire are provided in Appendices B1 and B2 respectively.

5.2.2 Conducting the Survey

The survey was to target contractors in addition to both public clients and clients' representatives. Clients were identified from the same sources as used for the initial survey (*refer* Section 4.4.2, Chapter 4). Contractors were identified from the following sources:

i. companies (contractors) that ranked in the top 200 in Key British Enterprises (Dun & Bradstreet, 1998) with annual turnover above £1.0 million;

ii. companies that registered with Chartered Institute of Building i.e. Chartered Building Company (CIOB, 1998);

Table 5.1 provides a summary of this survey. The rationale behind the sampling survey was similar to the initial survey, i.e. geographical spread; companies with professional / chartered status; key personnel with minimum three years contractor selection experience; and for building and civil engineering works (*refer* Section 4.4.2, Chapter 4).

Table 5. 1: Source of Questionnaire Samples

Type of respondents targeted (Source of data)	**No. of questionnaires sent**
Public client:	
• Housing Associations and Directory Yearbook (NFHA, 1998);	
• Municipal Year Book and Public Service Directory (Yorke, 1998);	250
Clients' representatives:	
• Association of Project Management Year Book (APM, 1998);	
• The Property Profession Chartered Surveyor Regional Directory (RICS, 1997);	200
Contractors	
• Chartered Building Company Directory and Handbook (CIOB, 1998);	
• Key British Enterprises (Dun & Bradstreet, 1998);	250
Total:	**700**

A total of 700 questionnaires were distributed with pre-paid and self-addressed envelopes.

5.2.3 Questionnaire Response

There were 122 public clients, 104 clients' representatives and 78 contractors responded to the survey (building and civil engineering works combined). In Component (2), 157 and 147 respondents answered the questionnaires for building and civil engineering works respectively. Whilst in Component (3), there were 150 respondents for building works and 139 respondents for civil engineering works. All respondents indicated that they had been involved in contractor prequalification (and tender evaluation) during the past three years, prior to survey. Details of the response may be observed in Table 5.2.

Table 5. 2: Questionnaire Response

Returned completed	Public client	Clients' representatives	Contractor	Totals
Component (2)				
Building	62	56	39	157
Civil E.	60	48	39	147
Component (3)				
Building	56	54	40	*150
Civil E.	54	48	37	**139

* 95.5 % of 157 (Building) respondents continued to Component (3).
** 94.6% of 147 (Civil Engineering Works) respondents continued to Component (3).

Table 5.3 shows the spread of respondents across the UK. The response from Northern Ireland, Scotland and Wales could be attributed to the low number of local authorities. According to the Municipal Yearbook and Public Service Directory (1998), in Direct Contracts Services department, there are: 21, 26 and 17 unitary councils, respectively, in Northern Ireland, Scotland and Wales. While in England there are 320 local authorities responsible for Direct Contracts Services. In Direct Labour Organsition (DLO) the figure is 283 in England as compared to 21, 29 and

19, respectively, in Northern Ireland, Scotland and Wales. The diversity in size and number of local authority depends very much on population and social-economic needs of that particular region.

Table 5. 3: Classification of Respondents' Location and Nature of Business

Location	*% of Respondents (Building & Civil E.)*
England (excluding London)	78.3%
London	13.4%
Scotland	2.0%
Wales & Northern Ireland	5.1%
	100%

The regions of the UK are diverse in size and population and in terms of their economic characteristics. Hence, there is much diversity between the regions of the UK in terms of construction company profiles (e.g. number and type of construction firms, size, nature of business and geographical location).

Furthermore, the location of construction firm headquarters may impact on the geographical spread of the response. Larger companies tend to have offices scattered around the east and central parts of England (particularly in London), but this does not necessarily restrict the geographical out reach of work. Examples of these companies could be found in Association of Project Management Yearbook (APM, 1998) and Key British Enterprises (Dun & Bradstreet, 1998) in Table 5.4.

Nevertheless, the geographical context of the survey was considered less important as the emphasis was on data (opinion) collection in regard to the LIA for both PC and PSC. In other words, to explore the opinions of clients and contractors, rather than to explain or to compare their differences in perception based on a geographical context.

Table 5. 4: Geographical Classification of the Private Construction Firms

Regions	*APM Year Book- 1998 (no. of firm)*	*Key British Enterprise, Dun-Bradstreet- 1998 (no. of firm)*
England	149 (92%)	204 (88%)
Scotland	7 (4%)	15 (6%)
Wales	3 (2%)	8 (3%)
N. Ireland	3 (2%)	6 (3%)
Totals:	162 (100%)	233 (100%)

5.3 ANALYSIS OF SURVEY DATA

Investigation of the use of PC among construction practitioners has been performed by many (e.g. Russell *et al.*, 1992; Ng *et al.*, 1999). Russell *et al.* (1992) found that public clients and clients' representatives viewed PC differently while private clients and construction managers viewed them similarly. Ng *et al.,* (1999) examined the diversity of opinion with regard to PC, during the prequalification process. They found that there are significant differences in perception between groups of architects, civil engineers, quantity surveyors, and project managers. This chapter focuses on differences in LIA among public clients, clients' representatives and contractors in building and civil engineering works.

In the present investigation, the study of PC (and PSC) placed emphasis on exploratory investigations of practitioners' opinions (i.e. LIA). Therefore, the analyses observed focused upon differences between; and correlation among the PC (and PSC), between the three sample groupings, for different work types.

Consequently, the analysis focused on findings of *differences* between opinions (where it lies) and *interaction* (effect of PC and / or organisation types upon LIA), for given types of construction projects. In order to achieve the above aims, two types of statistical tests were used i.e. non-parametric (Spearman Rank Correlation Coefficient test [SRCC] and the Kruskal-Wallis test) and parametric tests (analysis of variance [ANOVA]). Table 5.5 shows a summary of the use of these statistical tests in this chapter and in Chapter 6. The rationale and mechanisms of use of these statistical tests will be fully explained in the following sections.

Table 5. 5: Type of Statistical Tests

Type of test	Name of test	Nature of test
Non-parametric	Kruskal-Wallis	Look for significant *differences* (means) between samples
	SRCC	Bivariate analyses- exploring *relationships / correlation* between two pairs of samples.
Parametric	One-way ANOVA	Look for significant *differences* (means) between samples
	Two-way ANOVA	Investigation of both *interaction effects* and *main effects* of the independent variables to the dependent variable.
	Descriptive statistics	Summarising data e.g. confidence intervals, central tendency, variability, etc.

5.3.1 Survey Sample Workload and Contract Values

Table 5.6 shows the number and value of contracts reported by respondents based upon their past three years' company workloads. The total amount of contracts awarded was £5,914 million for 2,963 building contracts and, £8,469 million for 2,001 civil engineering contracts. These figures equate to an average of £2 million and £4.23 million for building and civil engineering contracts respectively. This is an indication of the scale and scope of work commonly found in the two sectors; civil engineering works are generally of higher value.

Table 5.6 shows that clients' representatives were responsible for much larger contracts. That is, an average of £2.58 million for building contracts and £6.48 million for civil engineering contracts among clients' representatives, compared to £0.76 million and £1.97 million respectively for public client respondents. This is attributed to the fact that the majority of public sector projects reported were repair and maintenance.

Table 5. 6: Survey Sample Workload and Contract Value

	Building Works			Civil Engineering		
	£ Million	*No.*	*Mean*	*(£ M)*	*No.*	*Mean*
Public	725	950	[a]0.76	1965	998	[b]1.97
	5914	*2963*		8469	*2001*	
Clients' Rs.	5189	2013	[a]2.58	6504	1003	[b]6.48
Contractor	3210	1671	1.92	4136	1021	4.05

Note: Building and civil engineering works consists of repair, maintenance and new construction works.
[a] *Average contract value for building project (public clients and clients' representatives combined) is £2 million (5914/£2963m).*
[b] *Average contract value for C.E. project (public clients and clients' representatives combined) is £4.23 million (8469/£2001m).*

5.3.2 Statistical Analysis Procedures

The analysis of survey data was performed using the statistical package i.e. SPSS version 9.0. Types of procedures used and the nature of each test are shown in Table 5.5. The following summarises the rationale underpinning the use of these statistical procedures:

i. SRCC test: to test for association between the rankings of PC, based upon LIA.

ii. Non-parametric test (Kruskall-Wallis test) and parametric test (one–way ANOVA): to investigate the power of statistical tests and, to verify the degree of violation of parametric assumptions of the use of observed data.

iii. Two-way ANOVA and Interaction Plot: to investigate the interaction effects and main effects of PC and organisation types on LIA.

iv. Error Bar Chart: to identify the confidence intervals of LIA for each PC and make comparisons among the sample groupings diagrammatically.

v. *Post-Hoc Multiple Comparison Procedure* analysis: to confirm exactly where the LIA differences lie (with the particular PC) among the three different sample groupings.

Russell *et al.* (1992) used SRCC and Kruskal-Wallis tests for quantitative analysis of prequalification criteria opinions, among US construction practitioners. Similar non-parametric tests were also used in Wong *et al* (2001b) findings. Parametric tests are more powerful and enable precise differences between sample data to be investigated (Norusis, 1995:p341). Therefore, the following analyses will concentrate upon the use of parametric tests in finding significant differences in LIA for PC, among the different groupings of respondents.

Use of these procedures and their mechanism is fully explained under each respective sub-heading in the following sections.

5.3.3 The Correlation Test: Respondents' Views on PC

In order to analyse respondents' views on PC (i.e. to study how important they are perveived and to observe the use of PC among respondents), the analysis first began with the study of LIA correlation (with regard to particular PC).

Statistical correlation describes an association between two varaibles, or as here, between the sets of ranks where the increments / decrement in one variable occurs together with increments / decrement in others (Cohen and Holliday, 1996:p83-84). The quantifiable relationship between two variables can then be measured by an index called the correlation coeffient (*op. cit.*, p87).

The *Spearman Rank Correlation Coefficient* (SRCC) test was employed in this instance, to test for the association of LIA between the combination of three pairs of sample groupings i.e. *public clients* and *clients' representatives*; *public clients* and *contractors*; and *clients' representatives* and *contractors*. The SRCC calculates the correlation of PC rankings (ranked accordingly based on LIA means). The value of correlation i.e. r can vary from -1 to 1, indicating negative or positive association respectively. A value of *zero* indicates no correlation; 1 indicates perfect positive correlation and –1 indicates reverse rankings correlation (Hayslett, 1988:p180; Ruddock, 1995:p97). In this correlation analysis, all sets of rankings for criteria based on LIA were tested statistically using SRCC; to find out if these sets of data closely correlated among public clients and clients' representatives, and contractor organisations.

To begin the test, all prequalification criteria identified from the literature were grouped into a randomised sequence under the headings of (1) building and (2) civil engineering works in the questionnaire. The mean LIA for each criterion was calculated based on aggregated sample response measure on the Likert scale, and as reported by respondents. By contrasting the sum of these aggregated responses for each criterion, a ranking exercise was therefore performed. Each criterion was assigned a rank in respect to the LIA. That is, highest LIA was assigned highest rank and vice-versa. Tables 5.7 and 5.8 show the observed LIA for each PC (building and civil engineering works) among the three sample groupings surveyed.

Having derived ranks for all PC based on LIA, the SRCC was then applied to the three sets of sample group rankings. Tables 5.9 and 5.10 show the SRCC test results for both building and civil engineering works respectively. Approximate correlation coefficients are: **0.88** between *public* clients and *clients' representatives*; **0.74** between *public* clients and *contractors*; and **0.87** between *clients' representatives* and *contractors* in building works (**0.83**, **0.76**, and **0.84** respectively in civil engineering works). All results are significant at the 0.0005 level.

According to Cohen and Holliday (1982:p83), coefficients of 0.19 and below represent very low association; 0.20 to 0.39 is low; 0.40 to 0.69 is modest; 0.70 to 0.89 is high; and 0.90 to 1 is very high. Thus, it can be concluded that there is significant statistical association between the ranking of PC assigned by clients' representatives, public clients and contractors (based on LIA), in both building and civil engineering works.

Table 5. 7: Observed LIA of 45 PC for Building Works

	Public		Clients' Rs.		Contractor	
Prequalification Criteria	*Mean*	*Rank*	*Mean*	*Rank*	*Mean*	*Rank*
1. Current work load	3.365	28.0	3.500	28.0	3.522	24.5
2. Location of home office/ place for business	2.808	39.0	3.088	38.5	3.000	39.0
3. Ability to innovate	2.692	41.0	3.147	35.5	3.261	34.0
4. Insurance Cover	4.500	3.0	3.888	19.0	3.087	36.5
5. Past performance in terms of time	4.373	9.0	4.441	5.5	4.217	7.0
6. Past performance in terms of cost	4.375	8.0	4.559	2.5	4.348	5.5
7. Quality performance record	4.404	6.5	4.559	2.5	4.174	8.0
8. Experience in particular work type(s)	4.404	6.5	4.441	5.5	4.522	3.0
9. Contractor maximum capacity	3.808	17.0	3.780	24.0	3.478	26.5
10. Staff training regime	3.221	33.0	3.059	40.0	2.565	43.0
11. Home office support	2.924	38.0	2.824	43.0	2.952	41.0
12. Annual turnover	3.308	30.0	3.147	35.5	3.391	31.0
13. Risk management system	3.627	22.0	3.118	37.0	3.452	28.0
14. Financial stability	4.462	4.0	4.529	4.0	4.087	12.5
15. Health and safety (record/awareness)	4.673	2.0	4.212	11.0	4.087	12.5
16. Technical ability and expertise	4.442	5.0	4.265	10.0	4.130	10.0
17. References / third parties	3.503	24.0	3.412	29.0	3.652	21.5
18. Bonding capacity	3.501	25.0	3.242	34.0	3.348	32.0
19. Environmental impact awareness	3.157	35.0	3.088	38.5	2.913	42.0
20. Design ability	2.492	43.0	3.270	33.0	2.996	40.0
21. Dispute and claim history	3.805	18.0	4.029	16.5	3.130	35.0
22.Experience: local or international	3.531	23.0	4.088	14.5	3.957	17.0
23. Resources(manpower/equipment/labour)	3.846	14.0	4.088	14.5	3.783	20.0
24. Project management skills.	3.746	19.0	4.029	16.5	3.950	18.0
25. Interface of contractor with others	3.452	26.0	3.735	25.0	3.478	26.5
26. Company size and organisation	3.314	29.0	3.294	32.0	3.522	24.5
27. Site management	4.021	10.0	4.211	12.0	4.000	15.5
28. Quality and experience of key personnel(s)	3.998	12.0	4.412	7.0	4.348	5.5
29. Reputation/Image	3.080	36.0	3.588	27.0	3.913	19.0
30. Employees and Subcontractors details	3.196	34.0	3.324	31.0	3.043	38.0
31. Understanding of contract/legal issues	3.294	32.0	3.331	30.0	3.304	33.0
32. Number of years in business	2.784	40.0	3.000	42.0	3.087	36.5
33. Past performance to particular project	3.692	20.0	4.118	13.0	4.130	10.0
34. Financial exposure (local or international)	3.296	31.0	3.828	20.0	3.589	23.0
35. Prior business relationship	3.019	37.0	3.794	22.0	4.043	14.0
36. Contractor negotiation skill	2.577	42.0	3.058	41.0	3.435	29.5
37. Past performance in client's previous project(s)	3.827	15.5	4.294	9.0	4.652	1.5
38. Company nationality	1.481	45.0	2.000	45.0	1.957	44.0
39. Trade union record	2.203	44.0	2.412	44.0	1.783	45.0
40. Contractor specific experience	3.393	27.0	3.787	23.0	4.000	15.5
41. Quality assurance and control procedure	3.628	21.0	3.706	26.0	3.652	21.5
42. Contractor success/failure contract record(s)	3.881	13.0	3.939	18.0	4.361	4.0
43. Credit rating	3.827	15.5	3.815	21.0	3.435	29.5
44. Management capability	4.020	11.0	4.302	8.0	4.130	10.0
45. Contractor capability to carry out the work	4.706	1.0	4.804	1.0	4.652	1.5

Note: A Likert scale from 1 to 5 is used, 1= no impact, 3= moderate impact, 5= high impact.

Table 5. 8: Observed LIA of 45 PC for Civil Engineering Works

Prequalification Criteria	Public *Mean*	Public *Rank*	Clients' Rs. *Mean*	Clients' Rs. *Rank*	Contractor *Mean*	Contractor *Rank*
1. Current work load	3.417	28.0	3.846	20.0	4.050	18.0
2. Location of home office/ place for business	2.833	38.0	3.000	42.0	3.167	38.0
3. Ability to innovate	2.583	41.0	3.385	35.5	3.583	30.5
4. Insurance Cover	4.542	6.0	3.769	24.0	3.250	35.5
5. Past performance in terms of time	4.375	8.0	4.385	6.5	4.417	8.0
6. Past performance in terms of cost	4.333	9.0	4.462	4.0	4.417	8.0
7. Quality performance record	4.500	7.0	4.385	6.5	4.333	10.5
8. Experience in particular work type(s)	4.583	5.0	4.385	6.5	4.667	3.0
9. Contractor maximum capacity	3.917	15.5	3.747	25.0	3.750	25.5
10. Staff training regime	3.125	35.0	3.077	41.0	3.083	39.0
11. Home office support	2.792	39.0	3.154	40.0	3.075	40.5
12. Annual turnover	3.208	31.0	3.462	32.5	3.417	32.5
13. Risk management system	3.625	25.0	3.231	38.5	3.917	20.5
14. Financial stability	4.792	1.0	4.538	2.5	4.167	14.5
15. Health and safety (record/awareness)	4.750	2.0	4.231	13.0	4.667	3.0
16. Technical ability and expertise	4.667	4.0	4.308	10.0	4.667	3.0
17. References / third parties	3.744	21.0	3.462	32.5	3.833	23.5
18. Bonding capacity	3.708	22.0	3.385	35.5	3.250	35.5
19. Environmental impact awareness	3.292	30.0	3.308	37.0	3.583	30.5
20. Design ability	2.542	42.5	3.731	26.0	3.075	40.5
21. Dispute and claim history	4.042	14.0	4.077	16.5	2.667	43.0
22. Experience: local or international	3.667	23.5	4.308	10.0	4.083	17.0
23. Resources(manpower/equipment/labour)	3.792	19.0	4.077	16.5	4.167	14.5
24. Project management skills.	3.875	17.0	4.308	10.0	4.154	16.0
25. Interface of contractor with others	3.333	29.0	3.692	27.0	3.833	23.5
26. Company size and organisation	3.667	23.5	3.462	32.5	3.667	28.0
27. Site management	4.127	12.0	4.244	12.0	4.000	19.0
28. Quality and experience of key personnel(s)	4.250	11.0	4.538	2.5	4.500	6.0
29. Reputation/Image	3.171	32.5	3.615	28.0	3.667	28.0
30. Employees and Subcontractors details	3.042	37.0	3.462	32.5	3.250	35.5
31. Understanding of contract/legal issues	3.125	35.0	3.482	30.0	3.417	32.5
32. Number of years in business	2.625	40.0	3.231	38.5	3.250	35.5
33. Past performance to particular project	3.750	20.0	4.154	14.5	4.333	10.5
34. Financial exposure (local or international)	3.475	27.0	3.835	21.0	3.879	22.0
35. Prior business relationship	3.125	35.0	3.538	29.0	3.750	25.5
36. Contractor negotiation skill	2.542	42.5	2.918	43.0	3.000	42.0
37. Past performance in client's previous project(s)	3.917	15.5	4.154	14.5	4.583	5.0
38. Company nationality	1.542	45.0	2.231	45.0	1.917	44.5
39. Trade union record	2.215	44.0	2.769	44.0	1.917	44.5
40. Contractor specific experience	3.602	26.0	3.830	22.5	4.250	12.5
41. Quality assurance and control procedure	3.171	32.5	4.000	18.0	3.917	20.5
42. Contractor success/failure contract record(s)	3.871	18.0	3.830	22.5	4.250	12.5
43. Credit rating	4.292	10.0	3.918	19.0	3.667	28.0
44. Management capability	4.125	13.0	4.335	6.5	4.417	8.0
45. Contractor capability to carry out the work	4.738	3.0	4.900	1.0	4.811	1.0

Note: A Likert scale from 1 to 5 is used, 1= no impact, 3= moderate impact, 5= high impact.

Table 5. 9: SRCC Test in Building Works

Organisations Types	*Non-parametric correlation*	*Public Client*	**Client's Representative**	*Contractor*
Public Client	Correlation Coefficient	1.000	-	-
	Sig. (2-tailed)		-	-
	N (PC)	45	-	-
Client's Representative	Correlation Coefficient	*.881**	1.000	-
	Sig. (2-tailed)	*.000*		-
	N (PC)	45	45	-
Contractor	Correlation Coefficient	*.737**	*.873**	1.000
	Sig. (2-tailed)	*.000*	*.000*	
	N (PC)	45	45	45

* *Correlation is significant at the 0.0005 level (2-tailed).*

Table 5. 10: SRCC Test in Civil Engineering Works

Organisations Types	*Non-parametric correlation*	*Public Client*	**Client's Representative**	*Contractor*
Public Client	Correlation Coefficient	1.000	-	-
	Sig. (2-tailed)		-	-
	N (PC)	45	-	-
Client's Representative	Correlation Coefficient	*.834**	1.000	-
	Sig. (2-tailed)	*.000*		-
	N (PC)	45	45	-
Contractor	Correlation Coefficient	*.755**	*.835**	1.000
	Sig. (2-tailed)	*.000*	*.000*	
	N (PC)	45	45	45

* *Correlation is significant at the 0.0005 level (2-tailed).*

Notwithstanding the above findings, a high level of association between the three sample groupings (in terms of LIA) does not show which variables are causing this relationship; or which are considered significantly different from others across the sample groupings. The following analyses discuss how these significant differences can be confirmed via the use of ANOVA. The ANOVA tests were used to find exactly where these differences lie.

5.3.4 ANOVA Assumptions

The assumptions for parametric tests have long been debated and remain to some extent unresolved (Bryman and Cramer, 1999:p118-119). ANOVA requires the assumptions of: (1) independent samples; (2) normal distribution of the population sample scores; and (3) equal sample variances (Norusis, 1995:p283). Detailed explanation of ANOVA assumptions were discussed in Chapter 4 (section 4.3.4) and are therefore not repeated here. In this empirical survey, the independence sample assumption is well conditioned since the response was based on individuals' experience and the samples were carefully selected from different organisations. The normality assumption can be determined by the comparison of test results from non-parametric and parametric tests, using the same data. The tests will be discussed in detail in section 5.3.5.

The assumption of equal (constant) variance can be checked by the *Levene test* (*refer* Chapter 4). However, in addition, by running the *Levene test* it may be interesting to know how these observed data (i.e. LIA) differ in variance among the three sample groupings. The term 'variance' (i.e. variability) is an expression showing the spread or dispersion of data around the mean, and is the square of the standard deviation (Bryman and Cramer, 1999:p116). It also refers to the extent to which individuals, objects, or scores differ from the grand mean of a sample on given characteristics or attributes (Walsh, 1990:p125).

The *Levene test* was employed to test the equality of variance in LIA for the PC across the three types of respondents (based upon LIA) for both building and civil engineering works. The outputs of both tests are presented in Table 5.11.

As can be seen, there are 12 PC in building works and 4 PC in civil engineering works (shown as bold in Table 5.11) whose LIA scores are significantly different across the sample groupings. These observed figures (unequal variance PC) represented only 27% and 9% of the overall data in building and civil engineering works respectively. This shows a minority of the LIA population being unequally distributed, and thus it could be that this gives impact to the power test statistic i.e. violations of parametric assumptions. Therefore, in order to verify the extent of this violation, it is prudent to run both non-parametric and parametric tests on the same set of data. If the test results from both analyses are not found to differ greatly, then it can be assumed that the data does not violate the assumption conditions (e.g. Bryman and Cramer, 1999:p119, Wong *et al.*, 2001b).

5.3.5 The Non-parametric and Parametric Tests for Violation Conditions

One-way ANOVA is a parametric test used to test a hypothesis about two or more population means. It compares: variability *between* the group means; and observed variability *within* group means (Norusis, 1995:p279-301).

The Kruskal-Wallis test is a non-parametric alternative to one-way ANOVA and assumes less stringent assumptions than the parametric test (Norusis, 1995:p349). In the present analysis, in order to investigate the extent of violation of the data, the non-parametric and parametric tests were both conducted. Tables 5.12 and 5.13 show comparison of both tests for data from building and civil engineering works respectively. The (full) results can be obtained from Appendices C1, C2 and D.

Table 5. 11: Test of Equal Variance across Organisation Types

Prequalification Criteria	Building *Levene Statistic*	*Sig.*	Civil *Levene Statistic*	*Sig.*
PC1	1.226	*.297*	.456	*.636*
PC2	1.430	*.244*	.398	*.674*
PC3	.037	*.964*	.067	*.935*
PC4	3.627	***.030***	4.801	***.013***
PC5	.020	*.980*	3.317	***.045***
PC6	1.416	*.247*	.646	*.529*
PC7	4.071	***.020***	.053	*.948*
PC8	1.596	*.208*	1.088	*.345*
PC9	2.128	*.124*	.579	*.565*
PC10	5.349	***.006***	.646	*.529*
PC11	1.857	*.161*	.522	*.597*
PC12	9.523	***.000***	1.718	*.191*
PC13	2.107	*.127*	1.289	*.285*
PC14	.679	*.509*	2.962	*.062*
PC15	5.685	***.005***	4.924	***.012***
PC16	.496	*.611*	.526	*.595*
PC17	1.668	*.194*	.182	*.834*
PC18	1.158	*.318*	.722	*.491*
PC19	1.803	*.170*	.332	*.719*
PC20	2.261	*.109*	.373	*.690*
PC21	3.787	***.026***	1.600	*.213*
PC22	6.283	***.003***	.401	*.672*
PC23	.944	*.392*	2.241	*.118*
PC24	2.594	*.079*	1.097	*.342*
PC25	3.587	***.031***	.589	*.559*
PC26	4.529	***.013***	1.741	*.187*
PC27	.696	*.501*	.062	*.940*
PC28	.050	*.951*	.109	*.897*
PC29	1.482	*.232*	.120	*.887*
PC30	1.703	*.187*	2.387	*.103*
PC31	4.038	***.020***	1.346	*.270*
PC32	1.420	*.246*	.863	*.429*
PC33	.156	*.856*	.682	*.511*
PC34	6.173	***.003***	1.159	*.323*
PC35	3.535	***.033***	1.105	*.340*
PC36	.365	*.695*	.269	*.765*
PC37	2.913	*.059*	.765	*.471*
PC38	.265	*.768*	.291	*.749*
PC39	.532	*.589*	.387	*.681*
PC40	1.243	*.293*	.002	*.998*
PC41	1.075	*.345*	.339	*.715*
PC42	.129	*.879*	.314	*.732*
PC43	1.407	*.249*	3.774	***.030***
PC44	.133	*.876*	1.624	*.208*
PC45	2.043	*.135*	2.307	*.111*

All PC arranged in the sequence as per Table 5.7 or Table 5.8 according to the number cited.
Significantly different PC at 0.05 level as shown in bold.

Table 5.12 shows 14 PC in the parametric test and 15 PC in the non-parametric test indicating significant differences in mean scores across the sample groupings for 'building works' data. Of these, 86% (12 out of 14) of the significantly different PC in the parametric test results and 80% (12 out of 15) of PC in the non-parametric tests are matching. In civil engineering works, it was found that 100% (all 8) of the significantly different PC in the parametric test and 89% (8 out of 9) of the significantly different PC in the non-parametric tests were consistently matching (Table 5.13).

Table 5. 12: Parametric and Non-Parametric Tests in Building Works

One-way ANOVA						*Kruskal-Wallis Test*		
		Sum of sq.	*Mean sq.*	*F*	*Sig.*		*Chi-sq.*	*Sig.*
***PC3**	Between G.	6.994	3.497	3.258	*.042*	***PC3**	6.8492	*0.033*
	Within G.	113.776	1.073					
***PC10**	Between G.	6.896	3.448	3.540	*.032*	**PC7**	6.9073	*0.032*
	Within G.	103.241	.974					
***PC15**	Between G..	7.331	3.665	7.092	*.001*	***PC10**	6.7600	*0.034*
	Within G.	54.784	.517					
***PC20**	Between G..	13.141	6.570	5.304	*.006*	**PC14**	6.8555	*0.032*
	Within G.	131.317	1.239					
***PC21**	Between G..	11.588	5.794	5.927	*.004*	***PC15**	11.0242	*0.004*
	Within G.	103.622	.978					
PC22	Between G..	7.154	3.577	4.016	*.021*	***PC20**	10.7802	*0.005*
	Within G.	94.403	.891					
PC28	Between G..	4.147	2.074	3.076	*.050*	***PC21**	11.2516	*0.004*
	Within G.	71.462	.674					
***PC29**	Between G..	12.559	6.279	7.586	*.001*	***PC29**	12.0038	*0.002*
	Within G.	87.741	.828					
***PC33**	Between G..	5.042	2.521	4.513	*.013*	***PC33**	8.7759	*0.012*
	Within G.	59.215	.559					
***PC35**	Between G.	21.697	10.848	12.849	*.000*	***PC35**	20.1240	*0.000*
	Within G.	89.496	.844					
***PC36**	Between G.	12.847	6.424	8.084	*.001*	***PC36**	11.7955	*0.003*
	Within G.	84.231	.795					
***PC37**	Between G.	11.933	5.966	7.378	*.001*	***PC37**	13.5882	*0.001*
	Within G.	85.719	.809					
***PC38**	Between G.	6.870	3.435	4.141	*.019*	***PC38**	10.3812	*0.006*
	Within G.	87.937	.830					
***PC40**	Between G.	6.886	3.443	3.590	*.031*	***PC40**	8.2055	*0.017*
	Within G.	101.675	.959					
						PC42	7.3554	*0.025*

Note: All PC arranged in the sequence as per Table 5.7 or 5.8 according to the number cited.
**PC constantly matching in both tests. All significantly different at 0.05 levels*

Drawing on the above results, it was found that the results do not differ greatly (based upon the same data). It can be concluded that the data used in both statistical tests was (reasonably) normal distributed and of equal variance. Therefore, the following discussion will focus upon the use of the parametric test to investigate each LIA i.e. the differences between and within those organisations' perceptions measured.

Table 5. 13: Parametric and Non-Parametric Tests in Civil Engineering Works

	Parametric (One-way ANOVA)					*Non-parametric (Kruskal-Wallis test)*		
		Sum of sq.	*Mean sq.*	*F*	*Sig.*		*Chi-sq.*	*Sig.*
***PC3**	Between G.	11.834	5.917	5.226	*0.009*	***PC3**	8.789	*0.012*
	Within G.	52.084	1.132					
***PC4**	Between G.	13.276	6.638	4.793	*0.013*	***PC4**	8.755	*0.013*
	Within G.	63.703	1.385					
***PC14**	Between G.	2.992	1.496	5.290	*0.009*	***PC14**	7.853	*0.020*
	Within G.	13.008	0.283					
***PC20**	Between G.	11.767	5.884	4.708	*0.014*	***PC20**	7.818	*0.020*
	Within G.	57.485	1.250					
***PC21**	Between G.	17.448	8.724	11.615	*0.000*	***PC21**	15.425	*0.000*
	Within G.	34.552	0.751					
***PC33**	Between G.	3.184	1.592	3.892	*0.027*	**PC32**	6.015	*0.049*
	Within G.	18.816	0.409					
***PC38**	Between G.	5.834	2.917	3.396	*0.042*	***PC33**	6.947	*0.031*
	Within G.	39.513	0.859					
***PC41**	Between G.	6.771	3.386	3.611	*0.035*	***PC38**	7.510	*0.023*
	Within G.	43.124	0.937					
						***PC41**	6.643	*0.036*

**PC constantly matching in both tests. All PC significantly different at 0.05 levels*

5.3.6 Two-way ANOVA

It is important to study the possible effects of two (independent) variables upon on a third (dependent variable), particularly, when the two independent variables may influence one another. From the survey data, the response variable (i.e. LIA) may be expected to show some variation according to external factors (type of PC or organisation types). For instance, some LIA may have been rated higher in one of the PC compared to others, similarly, it may (or may not) be due to a second factor i.e. being drawn from public client, clients' representatives or contractor organisations.

Thus, the anticipation is that some degree of 'interaction' may exist between PC and organisation type, which impacts upon LIA.

'Interaction' is when the effect of one variable is not the same under all the conditions of the other variables (Everitt, 1998). In statistical terms, 'interaction' applies when two or more explanatory (independent) variables do not act independently on a response (dependent) variable. Such interaction effects can be statistically tested and determined using two-way ANOVA. The *General Linear Model-Univariate* procedure (*Simple Factorial ANOVA* procedure in SPSS 7.5) is used to test the *interaction* and *main effect* hypothesis that the group means of the response variable (LIA) are equal.

Firstly, the *interaction* of PC and organisation types will be considered. The null hypothesis for the *two-way interaction* terms is that the effect of type of PC on the mean value of LIA is the same for all organisation types (i.e. no interaction exists to contribute an effect on LIA). Tables 5.14 and 5.15 show that the observed significance level for the no-interaction (null) hypothesis is 0.000 ($p<0.0005$), for both building and civil engineering works. The alternative hypothesis is therefore accepted, therefore, there is an interaction between PC and organisation types.

The remaining null hypothesis is that the *main effects* of PC and organisation types to the LIA are all the same. Tables 5.14 and 5.15 show that the observed significance levels in *main effects* analysis are 0.000 ($p<0.0005$) in both building and civil engineering works. Based upon these findings the null hypothesis for both *main* *effects* are rejected (building and civil engineering works). The results confirm that the *main effects* of PC and organisation types to the LIA means are not the same.

Table 5. 14: Two-way ANOVA for PC in Building Works

		Sum of Squares	*df*	*Mean Square*	*F*	*Sig.*
LIA Main Effects	(Combined)	1632	46	35	40	*.000*
	Organisation Types	23	2	12	13	*.000*
	PC	1608	44	37	42	*.000*
2-Way Interactions	Organisation Types / PC	197	88	2	3	*.000*
Model		2065	134	15	18	*.000*
Residual		4146	4725	1		
Totals:		6211	4859	1		

Table 5. 15: Two-way ANOVA for PC in Civil Engineering Works

		Sum of Squares	*df*	*Mean Square*	*F*	*Sig.*
LIA Main Effects	(Combined)	759	46	17	21	*.000*
	Organisation Types	17	2	9	11	*.000*
	PC	742	44	17	22	*.000*
2-Way Interactions	Organisation Types / PC	122	88	1	2	*.000*
Model		1002	134	7	10	*.000*
Residual		1568	20252	1		
Totals:		2570	21599	1		

Since there is an interaction between PC and organisation types, this indicates that the LIA relationships (i.e. means) were different among PC in respect of organisation types. For instance, it might be that public clients assigned one of the criteria (e.g. *dispute and claim history*) more importance than clients' representatives, while the same is not necessarily true for contractors. Therefore, it is appropriate to consider **which** PC and **type** of organisations when investigating the variance and relationships of LIA.

5.3.7 Interaction Plot

Figures 5.1 and 5.2 show an interaction plot of LIA for both building and civil engineering works. Non-parallel lines show the inconsistency of LIA in respect of each PC, for the three given types of organisations observed. The vertical axis shows values of LIA for prequalification criteria based upon their past three years' experiences; while the horizontal axis represents the 45 numbers of PC observed. An interaction is indicated when the three lines of the graph are not parallel. Diagrammatically, as can be seen from the non-parallel lines, a variety of interaction effects exist. The interaction plots also indicates that certain LIA are ranked highest in the public sector.

Since two-way ANOVA found that the *interaction effects* are statistically significant as shown in Figures 5.1 and 5.2, the following discusses how and where these significant differences occur. The *error bar* charts are plotted to diagrammatically show where these significant differences lay among the sample groupings.

5.3.8 Error Bar Chart

Mean is the most familiar measure to describe the central tendency or average of a distribution for a set of given variables' scores (Cohen and Holliday, 1996:p22). Investigation of respondents' means provides information about how a distribution of the means is centred / grouped together.

A confidence interval (CI) or confidence limit is used to indicate how representative a sample mean is, with regard to the population from which the sample was drawn (Holt, 1998b:p106).

Figure 5. 1: Interaction Plot in LIA for Building Works

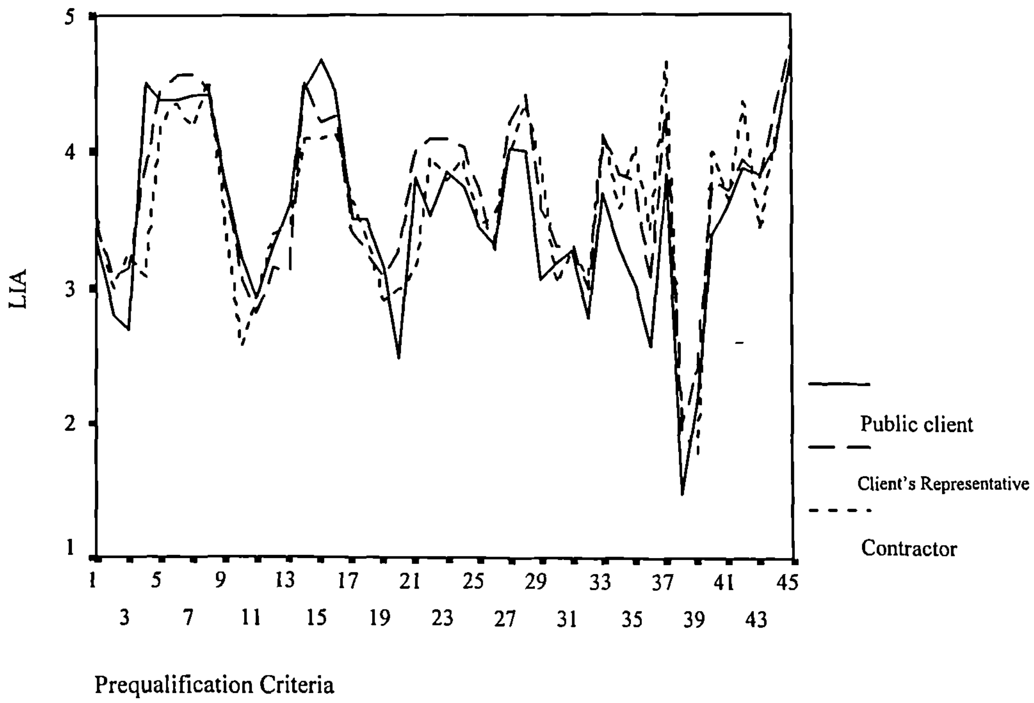
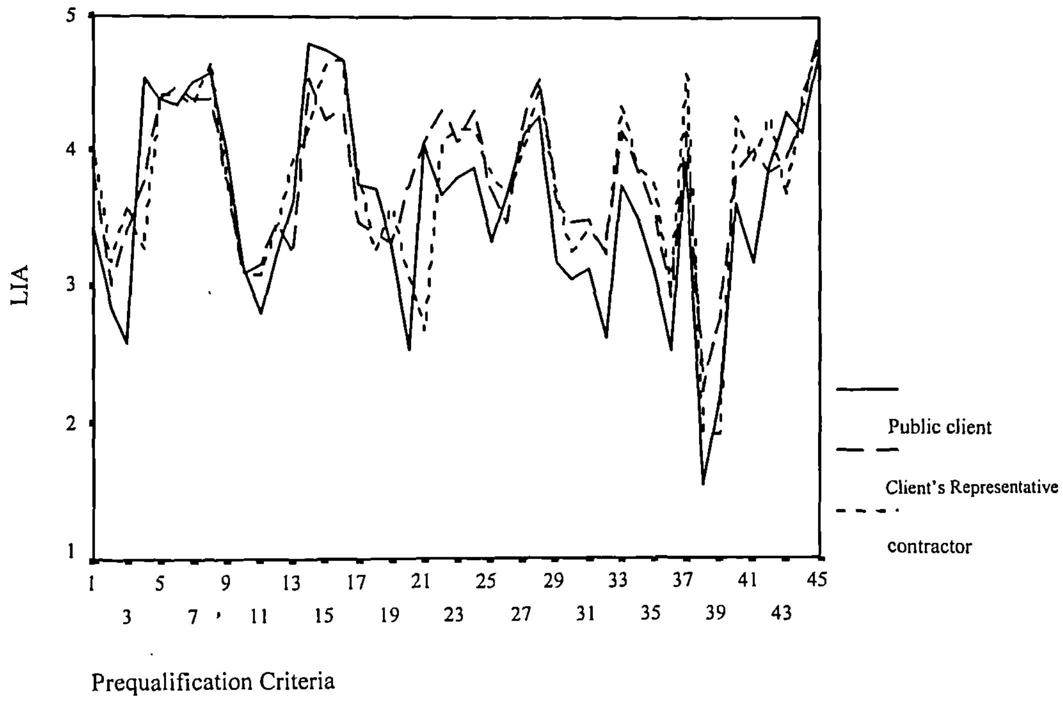


Figure 5. 2: Interaction Plot in LIA for Civil Engineering Works



It also gives predicted mean range for the same population. In the SPSS 9.0 package, an *error bar* chart can be generated to show CI for mean and the estimated dispersion of the population from which the data were drawn. Therefore, in order to further investigate these significant differences in means diagrammatically, an *Error Bar Chart was* used (Figures 5.3 and 5.4.).

The CIs of mean scores of each sample grouping are calculated via descriptive statistical analysis (as shown in Appendices E1 and E2). In this instance, the error bar is used to compare 95% CIs of LIA means for the different respondents' groupings. Figures 5.3 and 5.4 show error bar charts for 95% CI of LIA means in building and civil engineering works respectively.

For brevity (i.e. to reduce the number of the *error bars* in the two plots) and to have a cross-comparison between construction clients and contractors' opinions regarding PC and PSC; public clients and clients' representatives are combined. Each error bar is centred on the mean of a distribution and extends above and below to show a CI (Norusis, 1993:p541).

As can be seen from Figures 5.3 and 5.4, a majority of the 95% CI for clients is narrower than for contractors. This is because there are more respondents (Table 5.2) in this sample and hence less variation of LIA means (as compared to contractors). Figures 5.3 and 5.4 also indicate that most of the CIs overlap (clients and contractors) in both types of construction works, meaning that 95% CIs for estimated LIA means for client and contractors in both building and civil engineering works are very close. This also indicated that the tendency for degree of importance attached to the PC in clients and contractors are very similar. On this evidence, both clients and contractors attach equal importance to the LIA

Fully elucidated 95% CI figures for the 45 LIA means in building and civil engineering works are shown in Appendices E1 and E2 respectively. The 95% CIs *lower* and *upper bound* figures in Appendices E1 and E2 show that most of the CIs overlap among the sample groupings.

Figure 5. 3: Error Bar Chart - LIA Confidence Intervals for Building Works

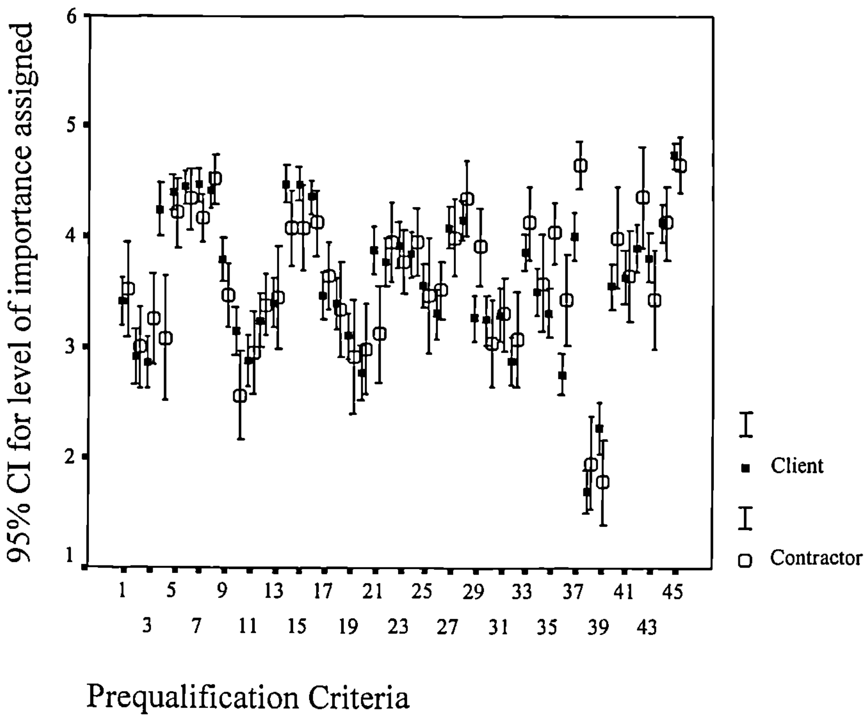
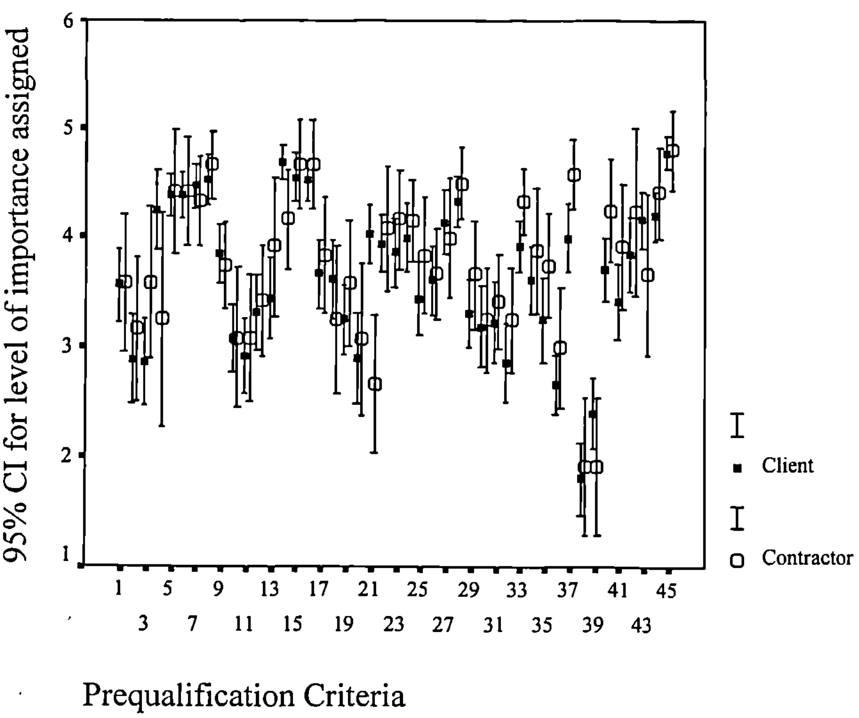


Figure 5. 4: Error Bar Chart - LIA Confidence Intervals for Civil Engineering Works



The SRCC and one-way ANOVA tests only confirm the relationship of PC among organisation types and the 'existence' of differences in LIA of the PC across the organisation types. In order to find the 'true' differences in LIA means (for the particular PC) among these sample groupings, the *post-hoc multiple comparisons* procedure was used.

5.3.9 Investigating for 'True' Differences

Analysis of variance (i.e. one-way ANOVA and Kruskall-Wallis tests) will only confirm that the means of several groups are not the same. But it does not pinpoint exactly **where** the difference(s) lie. For instance, to investigate which group(s) of respondents' are significantly different among the sample groupings, based on the

LIA means of the observed PC. The post-hoc multiple comparison confirms exactly where such differences exist among the respondents' groupings. There are many multiple comparison procedures available. The *Bonfferroni* procedure is used in this analysis (Norusis, 1993:p273; Holt, 1998b:p108). In order to perform the multiple comparisons among the sample groupings' LIA opinions, a 0.017 level of significant was used. The level of significance can be interpreted as a measure of the strength or cut off point that a significant difference exists among the sample groupings. For *three* groups post-hoc multiple comparison the significant level is 0.017 (0.05/3). This significant level is modified to take account of the fact that more than one comparison is being made. Details of level significant for post-hoc multiple comparison can be found in Bryman and Cramer (1999:p106,161) and Russell *et al's.*, (1992).

Appendices F1 and F2 show the results of post-hoc multiple comparisons in building and civil engineering works. For brevity, only significantly different PC among the respondent groupings are shown in Table 5.16. There are 8 PC in building works and 4 PC in civil engineering works that are statistically different among the sample groupings. Discussion of these 'true' differences is provided in the following sections.

5.4 DISCUSSION OF THE FINDINGS

The post-hoc multiple comparison analysis results shows that three sample groupings (i.e. public clients, clients' representatives and contractors) viewed the importance of certain PC differently in their prequalification practices. In building works, these criteria are:

i. insurance cover (PC4);

ii. financial stability (PC14);

iii. health and safety (PC15);

iv. design ability (PC20);

v. dispute and claim history (PC21);

vi. reputation and image (PC29);

vii. prior business relationship (PC35);

viii. contractor negotiation skill (PC36);

ix. and past performance in clients' previous works(s) (PC37).

Table 5. 16: Post-Hoc Multiple Comparison: Building and Civil Engineering Works

Building *PC*[1]		**Mean*[2]		*Mean*	*Mean Difference*[3]	*Std. Error*	*Sig.*
PC4	Public client	*4.500*	Contractor	3.087	1.41	0.28	*.000*
PC15	Public client	*4.673*	Client's Rs.	4.212	0.46	0.16	*.013*
			Contractor	4.087	0.59	0.18	*.005*
PC20	Client's Rs.	*3.270*	Public client	2.492	0.78	0.25	*.006*
PC21	Client's Rs.	*4.029*	Contractor	3.130	0.90	0.27	*.003*
PC29	Contractor	*3.913*	Public client	3.080	0.83	0.23	*.001*
PC35	Contractor	*4.043*	Public client	3.019	1.02	0.23	*.000*
	Client's Rs.	*3.794*	Public client	3.019	0.78	0.20	*.001*
PC36	Contractor	*3.435*	Public client	2.577	0.86	0.22	*.001*
PC37	Contractor	*4.652*	Public client	3.827	0.83	0.23	*.001*
Civil engineering works							
PC4	Public client	*4.542*	Contractor	3.250	1.29	0.42	*.012*
PC14	Public client	*4.792*	Contractor	4.167	0.63	0.19	*.006*
PC20	Client's Rs.	*3.731*	Public client	2.542	1.19	0.38	*.011*
PC21	Client's Rs.	*4.077*	Public client	4.042	0.04	0.31	*.000*
			Contractor	2.667	1.41	0.34	*.000*
	Public client	*4.042*	Contractor	2.667	1.38	0.31	*.000*

[1] *All PC arranged in the sequence as per Table 5.7 or 5.8 according to the number cited.*
[2] *Highest mean values among the significantly different sample groupings*
[3] *The mean difference is significant at the 0.017 level.*

5.4.1 Building Works

In building works, there were 8 PSC significantly different among the three types of respondents. The following discusses the significant difference of these PSC.

5.4.1.1 Insurance Coverage

Public clients viewed *insurance coverage* (PC4) significantly different from contractors, and *health and safety* (PC15) significantly different from both clients' representatives and contractors. Public clients placed more emphasis on these criteria compared to the other respondent groups.

Contracting is a risky business at any time, and therefore insurance inevitably plays an important part in the construction process. The extent of insurance coverage is specific and always linked to the nature of the project. Often, a contractor is more likely to arrange a 'blanket' policy to obtain coverage for a full range of a contractor's construction activities, throughout the year (Smith and Carl, 1986). This is to indemnify the employer against any claim arising out of injury / death to any person or damage to property. Insufficient insurance coverage may give rise to contractor's (and client's) financial difficulty as a consequence of project delay or failure. Due to this circumstance, a client may not be compensated in the event of an incompleted project. Furthermore, there are also significant administration and 'frustration' costs of replacing a contractor (incurred in the case of contractor failure) to continue the contract.

5.4.1.2 Health and Safety

The construction industry has long been criticised for its poor health and safety record (Samelson *et al.*, 1981). Samelson and Raymond (1982) focused on selection of a 'safe' contractor in reducing construction costs. They found that large numbers of American construction costs were due to improper selection particularly with respect to safety criteria. From their survey, safety performance was found to play a vital role in cost savings derived from the costs of compensation, insurance and other hidden costs. Samelson and Raymond (*ibid.*) suggested that safety should be used to remove contractors with poor safety performance from tender lists. To reflect its importance, safety needs to be weighted as a factor in the selection process with regard to the overall cost, quality and schedule impacts.

Indeed, lack of health and safety awareness has also been stressed in the UK construction industry (Latham, 1994). The health and safety policy promoted and enforced by The Health and Safety At Work Act 1974 (HASWA 74) is applicable throughout the UK. Under this act three major parties are involved i.e. duties of employer to employees; duties of employers to people other than their employees; and duties of employees to themselves and other persons (HMSO, 1990).

Additionally, the Construction (Design and Management) Regulations 1994 (CDM), enforced on 31st March 1995 play a vital role in promoting health and safety awareness in UK construction industry. The CDM regulations enforce every person engaged in design, management and execution of construction projects to comply with the principles of health and safety regulations (Joyce, 1995). The implication of health and safety commitments can also be found in public sector authorities' prequalification questionnaires during selection of tenderer(s). Ironically, health and safety forms part of many contractor selection processes. Needless to say, the advantages of selecting a 'safe' contractor have become more apparent.

5.4.1.3 Design Ability

Clients' representatives viewed *design ability* (PC20) with significant difference from public clients. This could be attributed to difference in project size and contract value undertaken by these two sample groupings. As can be seen from Table 5.6, the clients' representatives were responsible for much larger contract values (i.e. an average of £2.58 million and £6.48 million per project, respectively, in building and civil engineering project) compared to public clients (i.e. an average of £0.76 million and £1.97 million per project, respectively, in building and civil engineering project). It is no surprise why clients' representatives viewed this criterion more important than public clients.

5.4.1.4 Prior Business Relationship

Prior business relationships (PC35) were regarded more important by clients' representatives. These enhance working relationships and ease communication between clients and contractors, particularly, in large and complicated building projects. Good working relationships encourage teamwork and the possibility of establishing long term partnering-based relationships. The development of long-term relationships was considered one of the most important criteria to improve construction industry performance (Latham, 1994; Egan, 1998). Furthermore, it reduces conflict and litigation and improves productivity and competitiveness. Recent findings reveal that a close working relationship approach (i.e. partnering) rather than traditional contract-based, competitive selection practices are increasingly being used in the construction industry (Holt and Fraser, 1999; Wong *et al.*, 2000b).

5.4.1.5 Dispute and Claim History

Dispute and claim history (PC21) may indicate the likelihood of experiencing contractual disputes. From the empirical survey, it seems that a contractor's inability to carry out the obligation of a legally binding contract caused great concern to clients' representatives. According to Holt (1995), project cost overruns are often caused by: price fluctuations; variations in the works; and monetary claims by the contractors. The latter constituted contractors' 'opportunistic behaviour' of claim tendency and it could be more likely to trigger contract litigation / dispute between clients and contractors. *Dispute and claim history* may also be caused by other intervening factors such as a contractor's failure to complete a contract, and time / cost overruns by contractors.

5.4.1.6 Contractors' Views

Contractors considered: *reputation and image* (PC29); *prior business relationship* (PC35); *contractor negotiation skill* (PC36); and *past performance in clients' previous project(s)* (PC37) to be significantly different and more important than by public clients. This could be attributed to contractors' opinions that these criteria govern their 'chances' to be included on tender lists. It is worth noting that, some of these criteria e.g. *reputation and image; prior business relationships;* and *negotiation skill* are difficult to quantify. However, these criteria may be able to give a good first 'feel' or a good impression to clients of a contractor or of their abilities.

5.4.2 Civil Engineering Works

The post-hoc multiple comparisons studies of respondents' LIA for civil engineering works show that there are less PC having significant differences compared to 'building' projects. As shown in Table 5.16, there are only 4 significantly different PC among the three respondent groupings. Public sector clients viewed *insurance cover* (PC4) and *financial stability* (PC14) significantly different from contractors. Importance of *insurance cover* (PC4) has been previously highlighted and may be due to the need to safeguard public expenditure

5.4.2.1 Financial Stability

The construction industry is a high-risk business. The number of insolvencies is higher than other industry sectors (Abidali, 1990, *see also* Tables 2.3 and 2.4). Contractors' *financial stability* is arguably one of the most important factors and has been consistently cited by many as worthy of evaluation in prequalification (Hunt *et al.*, 1966; Russell, 1991; Russell and Jaselskis 1992a; Holt, 1995; Hatush and Skitmore, 1997b). There are a variety of views / methods (how) to predict and select a contractor in good financial performance (*ibid.*).

The financial stability of a contractor determines whether the company will stand or fall. Clearly, if the financial failure of a contractor can be recognised at the prequalification stage, the risk of project failure can be minimised. It is not surprising that public clients viewed this criterion with more importance (i.e. highest LIA) than clients' representatives and significantly different from contractors.

5.4.2.2 Design Ability

Clients' representatives are more concerned with *design ability* (PC20) and *dispute and claim history* (PC21). The importance of *design ability* may be due to the complex nature of such projects and the need for early contractor involvement (i.e. contribution of contractor's design proposals). Without doubt, this factor strengthens the requirements of contractors design ability during the design and / or construction stage. The significant differences of these criteria are also found in the building work. Detailed rationale has also been highlighted previously.

5.4.2.3 Dispute and Claim History

Results from the multiple comparison analysis shows that *dispute and claim history* (PC21) is of high importance to clients' representatives. This criterion might cause 'disaster' to clients if contractors are unable to complete projects on time and to budget, particularly, for commercial projects. The importance of this criterion has been previously discussed for building works.

To summarise, the above findings show that, even though the overall rankings of PC were highly correlated among the organisation types (i.e. via the SRCC test), the LIA assigned to each criterion was affected by the type of PC, type of organisation and type of project.

5.5 SUMMARY

This chapter encompassed three main sections representing questionnaire design, empirical survey of UK construction practitioners and, finally the statistical analyses. The research findings facilitate additional knowledge in PC. For instance, identifying significant views and differences of LIA for each prequalification criterion among the organisation types. Clients are more aware of *time* and *cost overruns* in both building and civil engineering works. In addition, clients' representatives viewed: *design ability, prior working relationships,* and *dispute / claim history* as their major concerns.

Contractors viewed: *reputation and image*; *prior business relationship; contractor negotiation skill;* and *past performance in clients' previous project(s)* attributes of greater influence, maybe because they need to 'impress' clients during prequalification. *Prior working relationships* are linked to past performance on clients' previous contracts. This is important for contractors as it make clients feel 'secure' (based on previous performance) and encourages a 'good' relationship with clients. Clearly, at prequalification stage it is desirable for contractors to impress clients and consequently achieve an invitation to tender. It is obvious that prequalification may not be regarded as an isolated exercise by contractors, but to secure their opportunity they must equip themselves to convey their potential ability to meet clients' expectations.

Statistical techniques were used to identify the significant differences among the PC used in different projects and for given types of organisation. The correlation tests found that most of the PC are perceived equally significant. However, levels of importance attributed to each varies among the organisations surveyed and types of project undertaken.

These findings provide useful information for clients regarding 'up-to-date' prequalification criteria preferences. For contractors, the empirical survey offers useful feedback as to what prequalification criteria are essential to meet clients' prequalification evaluation aspirations. Chapter Six discusses tender evaluation criteria i.e. project-specific criteria (PSC) and similar statistical treatments (in this chapter) will be use in Chapter Six.

CHAPTER 6

ANALYSIS OF TENDER EVALUATION CRITERIA

6.0 INTRODUCTION

The 'lowest-price wins' philosophy has been a consistent theme of contractor selection over the years. To comprehensively elucidate this selection preference and, compare it with the use of a multi-criteria selection (MCS) approach in the tenderer evaluation process, this chapter investigates MCS. That is, *project-specific criteria* (PSC) and lowest-price selection practices of UK construction clients, in both building and civil engineering works. These are looked at in detail via results of the empirical survey.

This chapter provides further insight into the evaluation of contractors' attributes (i.e. PSC). Levels of importance assigned (LIA) for each criterion were analysed (i.e. quantitative analysis of the differences in opinions, variance among the respondents). Importance attached by construction clients to the 'lowest-price wins' philosophy is also presented. Contrast was made between the MCS approach and the 'lowest-price wins', option among the surveyed construction clients both in building and civil engineering works.

Those data analysed were obtained from the second industry-wide questionnaire survey (*refer* Chapter 5). Statistical techniques used for analysing PSC are similar to the techniques explained and used in analysis of prequalification criteria in Chapter 5. Having analysed these PSC data, an increased use of PSC among the survey of construction clients was found. The realisation that cost has to be tempered with evaluation of PSC in an attempt to identify value for money, is also highlighted.

6.1 TENDER EVALUATION

Tender evaluation is performed once prequalified tenderers have submitted their formal tender. The scrutiny team may consist of in-house experienced personnel, or clients' representatives (consultants and construction specialists). Time and cost incurred in this contractor assessment mainly rely on the nature of tenderers' information and types of assessment methods used during this particular evaluation process.

The earlier literature review (Chapter 3) showed that tender evaluation has received a minimal amount of attention in the UK industry (Merna and Smith, 1990; Holt *et al.*, 1995a). It has been the tendency that award of contracts is merely on comparison of tender price i.e. 'lowest-price-wins' practice (*ibid.*). They found that such practice allowed all tenderers entered into tender competition, very often taking little account of other parameters (e.g. a contractor's financial soundness, management capabilities, technical expertise / capability, etc.) during tender evaluation.

However, lowest-price does not guarantee the overall lowest project cost upon project completion (Lewis, 1984; Pearson 1985; Grogan, 1992; Dawood 1994; Pasquire and Collin; 1997). Further, such a philosophy poses a high risk to the client since there is an increased possibility of (e.g.) financial collapse of contractor, bad performance, delay in completion, cost overruns and so on (Voster, M. 1977; Russell and Jaselskis 1992b; Kwakye, 1994; Holt *et al.*, 1995a).

Williamson (1975) defined the *cost of transaction* as the cost of tendering, negotiating and compiling the contract i.e. *ex-ante cost*; whilst the cost for executing the contract and its policy of resolving disputes arising from the contracted work as *ex-post cost*. Meanwhile, Lingard *et al.*, (1998) investigated the intrinsic link between *ex-ante cost* for entering a contractual relationship and the use of a variety of contractor evaluation methods. They found that methods used in contractor evaluation have a vital impact to the cost of a transaction; the *ex-ante cost* could be higher than the ex-*post cost* in multi-criteria contractor selection models (compared to traditional competitive tender methods). One reason for this is that quantitative multi-criteria evaluation needs to address a broader range of contractors' information (e.g. contractors' likelihood of successful project execution, identification of uncertainty, assessment of competence). Nevertheless, the measure reduces substantial *ex-post* costs via avoiding contract(s) being awarded to 'risky' contractor(s) and eliminating the multitude of problems that inevitably follow the selection of an incompetent and / or unqualified contractor(s).

Clearly, the rationale for using an objective tender evaluation method is that, clients may accomplish most objectives (reduce *ex-post cost* and minimise contract failure).

6.2 EVALUATION OF PSC

Perceptions regarding the role of PSC were initially observed from the literature review (Chapter 3). These observations were adopted in the industry-wide questionnaire survey as discussed in Chapter 5. There were 150 and 139 questionnaires returned completed by construction practitioners in PSC section (i.e.

Component (3)) for building and civil engineering works respectively. Of which, 56 public clients, 54 clients' representatives and 40 contractors were involved in building works (54, 48 and 37 respectively, in civil engineering works. Refer Table 5.2 for details). In Component (3), a total of 9 main PSC categories were identified. These categories are:

i. manpower resources;
ii. equipment resources;
iii. project management capabilities;
iv. geographical location knowledge;
v. location of home office;
vi. contractor's capacity;
vii. project execution capabilities;
viii. technical-economic analysis; and
ix. other relevant PSC (for particular types of work).

Results of the industry-wide survey for the 37 PSC attributed to these 9 categories are listed in Tables 6.1 and 6.2 for building and civil engineering works respectively. There were 9 categories of the PSC listed in the clients' questionnaire and 8 categories in the contractors' questionnaire (*refer* Appendices B1 and B2 for details). Category (viii) was not included in the contractor's questionnaire since this category concentrated upon investigation of clients' preferences in comparison to tenderer price during tender evaluation. Category (viii) will be discussed in conjunction with clients' final selection preferences (i.e. lowest-price selection preferences) in the later sections.

Table 6. 1: Observed LIA of 37 PSC for Building Works

Project-specific criteria	Public		Client's R.		Contractor	
	Mean	*Rank*	*Mean*	*Rank*	*Mean*	*Rank*
Manpower Resources						
1. Quality and quantity of human resources	3.982	10.0	4.114	9.5	3.913	10.0
2. Quality and quantity of managerial staff	4.000	8.0	4.286	5.0	4.261	5.0
3. Amount of decision-making authority on site	3.471	22.0	3.851	15.0	3.652	17.0
4. Amount of key personnel for the project	3.961	11.0	4.229	6.0	3.913	10.0
Equipment Resources						
5. Type of plants and equipment available	3.156	29.0	2.971	31.0	2.957	28.5
6. Size of equipment available	2.902	30.0	2.857	33.0	2.739	31.0
7. Condition and availability equipment	3.431	23.0	2.886	32.0	2.957	28.5
8. Suitability of the equipment	3.567	19.0	3.171	28.0	3.217	22.5
Project Management Capabilities						
9. Number of professional personnel available	3.596	18.0	3.629	20.0	3.696	15.0
10. Type of project control and monitoring procedures	3.692	17.0	4.114	9.5	3.870	12.0
11. Availability of project management software	2.490	35.0	2.829	34.0	2.826	30.0
12. Cost control and reporting systems	3.481	21.0	3.657	19.0	3.565	19.0
13. Ability to deal with unanticipated problems	4.125	6.0	4.543	2.0	4.522	2.5
Geographical Familiarities						
14. Contractor's familiarity with weather conditions	2.327	36.0	2.543	37.0	2.261	32.0
15. Contractor's familiarity with local labour	2.692	32.0	3.200	27.0	3.261	20.0
16. Contractor's familiarity with local suppliers	2.596	34.0	3.257	25.0	3.217	22.5
17. Contractor's familiarity with geographic area	2.712	31.0	3.057	30.0	3.217	22.5
18. Relationship with Local Authority	3.780	15.0	3.086	29.0	3.217	22.5
Location of Home Office						
19. Home office location relative to job site location	2.183	37.0	2.771	35.0	3.087	27.0
20. Communication & transportation- office to job site	2.683	33.0	2.743	36.0	3.130	26.0
Capacity						
21. Current workload	3.750	16.0	3.886	14.0	3.652	17.0
22. Maximum resource/financial capacity	4.231	3.0	4.143	7.0	3.913	10.0
23. Finance arrangements	4.019	7.0	3.686	18.0	3.739	14.0
Project Execution to the Proposed Project						
24. Training or skill level of craftsmen	4.173	4.0	3.833	16.0	3.783	13.0
25. Productivity improvement procedures and awareness	3.327	25.0	3.408	24.0	3.174	25.0
26. Site organisation, rules and policies (Health & Safety etc.)	4.288	2.0	3.896	13.0	4.043	7.5
27. Engineering co-ordination	3.246	27.0	3.710	17.0	3.652	17.0
Other Project-specific Criteria						
28. Actual quality achieved on similar works	4.157	5.0	4.371	3.0	4.522	2.5
29. Experience with specific type of facility	3.902	13.0	4.114	9.5	4.130	6.0
30. Proposed construction method	3.997	9.0	4.057	12.0	4.043	7.5
31. Ability to complete on time	4.746	1.0	4.686	1.0	4.696	1.0
32. Actual schedule achieved on similar works	3.885	14.0	4.324	4.0	4.391	4.0
Technical-economic Analysis						
33. Comparison of client's estimate with tender price	3.942	12.0	4.114	9.5		
34. Comparison between proposal and average tender prices	3.173	28.0	3.600	23.0		
35. Comparison for client's and proposed direct cost	3.500	20.0	3.617	21.0		
36. Contractor's errors- proposed construction method/procedure	3.383	24.0	3.600	22.0		
37. Proposals review- unit price/labour cost/resources schedule	3.294	26.0	3.229	26.0		

Note; A Likert scale from 1 to 5 is used, 1= not important, 3= moderate, 5= extremely important

Table 6. 2: Observed LIA of 37 PSC for Civil Engineering Works

Project-specific criteria	Public		Client's R.		Contractor	
	Mean	*Rank*	*Mean*	*Rank*	*Mean*	*Rank*
Manpower Resources						
1. Quality and quantity of human resources	4.000	9.5	4.200	9.5	4.000	12.0
2. Quality and quantity of managerial staff	4.120	8.0	4.400	4.5	4.286	6.5
3. Amount of decision-making authority on site	3.760	16.5	3.919	17.0	3.643	19.0
4. Amount of key personnel for the project	3.840	15.0	4.400	4.5	4.143	9.0
Equipment Resources						
5. Type of plants and equipment available	3.400	24.0	3.067	32.5	3.214	25.0
6. Size of equipment available	3.000	31.0	2.933	35.5	2.929	28.5
7. Condition and availability equipment	3.480	23.0	3.067	32.5	3.214	25.0
8. Suitability of the equipment	3.560	20.0	3.467	22.5	3.643	19.0
Project Management Capabilities						
9. Number of professional personnel available	3.760	16.5	3.600	21.0	3.929	13.0
10. Type of project control and monitoring procedures	3.880	13.5	4.400	4.5	3.857	15.0
11. Availability of project management software	2.660	35.0	3.133	30.5	2.929	28.5
12. Cost control and reporting systems	3.500	22.0	3.667	20.0	3.571	21.0
13. Ability to deal with unanticipated problems	4.380	3.0	4.533	2.0	4.857	1.0
Geographical Familiarities						
14. Contractor's familiarity with weather conditions	2.640	36.0	2.867	37.0	2.429	30.0
15. Contractor's familiarity with local labour	3.080	28.5	3.267	28.5	3.286	22.5
16. Contractor's familiarity with local suppliers	2.960	32.0	3.000	34.0	3.214	25.0
17. Contractor's familiarity with geographic area	2.680	34.0	3.133	30.5	3.286	22.5
18. Relationship with Local Authority	3.351	26.0	2.933	35.5	3.143	27.0
Location of Home Office						
19. Home office location relative to job site location	2.220	37.0	3.267	28.5	2.214	32.0
20. Communication & transportation- office to job site	2.780	33.0	3.333	26.5	2.357	31.0
Capacity						
21. Current workload	3.920	12.0	4.133	12.0	3.786	16.5
22. Maximum resource/financial capacity	4.440	2.0	4.200	9.5	4.286	6.5
23. Finance arrangements	4.200	5.0	3.800	18.0	3.923	14.0
Project Execution to the Proposed Project						
24. Training or skill level of craftsmen	4.160	6.5	4.076	13.0	3.786	16.5
25. Productivity improvement procedures and awareness	3.080	28.5	3.419	24.0	3.643	19.0
26. Site organisation, rules and policies (Health & Safety etc.)	4.160	6.5	4.224	7.0	4.143	9.0
27. Engineering co-ordination	3.592	19.0	3.924	16.0	4.071	11.0
Other Project-specific Factors / Criteria						
28. Actual quality achieved on similar works	4.000	9.5	4.400	4.5	4.643	3.0
29. Experience with specific type of facility	3.880	13.5	4.200	9.5	4.429	4.5
30. Proposed construction method	3.956	11.0	4.000	14.5	4.143	9.0
31. Ability to complete on time	4.560	1.0	4.667	1.0	4.786	2.0
32. Actual schedule achieved on similar works	3.712	18.0	4.200	9.5	4.429	4.5
Technical-economic Analysis						
33. Comparison of client's estimate with tender price	4.240	4.0	4.000	14.5		
34. Comparison between proposal and average tender prices	3.040	30.0	3.333	26.5		
35. Comparison for client's and proposed direct cost	3.394	25.0	3.467	22.5		
36. Contractor's errors- proposed construction method/procedure	3.517	21.0	3.733	19.0		
37. Proposals review- unit price/labour cost/resources schedule	3.217	27.0	3.400	25.0		

Note; A Likert scale from 1 to 5 is used, 1= not important, 3= moderate, 5= extremely important

6.3 DATA COLLECTION

The data used for analysis of PSC were obtained from the (second) industry-wide questionnaire survey as described in Chapter 5 (Appendices B1 and B2, Component-3). The opinions regarding use of these evaluation criteria for each particular PSC were measured in terms of LIA, using a five point Likert scale, where 1= no importance, 3 = moderate importance, and 5 = extremely important. The details of questionnaire survey method, design of the questionnaire, and questionnaire response were all discussed in Chapter 5 and therefore not repeated here.

Public clients and clients' representatives were invited to provide LIA in regard to the PSC used in their past three years' tender evaluation experiences. In the clients' questionnaire (for both public client and client's representative, in Appendix B1, Question-6), clients' opinions regarding final selection preferences (i.e. lowest-price practices) were also investigated. The results are compared, and detailed discussion of clients' final selection preferences is now presented.

6.4 ANALYSIS OF PSC

The use of statistical treatments presented in this chapter are similar to that described in Chapter 5. That is, to investigate the correlation, relationships between and significant differences between each PSC (based upon the LIA) and among the sample groupings. As a reminder, these procedures are:

i. Spearman Rank Correlation Coefficient (SRCC) test;

ii. Two-way ANOVA;

iii. Error bar chat; and

iv. Post hoc multiple comparisons.

The main features and mechanisms of the above tests are discussed in Chapter 5. The following analyses will mainly concentrate on the quantitative analysis of the survey data and subsequent discussion of the findings.

6.4.1 Correlation Test

Tables 6.1 and 6.2 show the 37 PSC, arranged under 9 main PSC headings for both building and civil engineering works respectively. To begin with, the observed LIA for each PSC were calculated based upon the overall LIA scores observed from respondents for all evaluation criteria. The ranking exercise was then carried out based on the magnitude of LIA mean response for each particular PSC (i.e. higher mean response = higher rank and vice-versa). Results of the ranking are shown in Tables 6.1 and 6.2.

Tables 6.3 and 6.4 show the correlation coefficients (r) for building works. That is, **0.83** between *public* clients and *clients' representatives*; **0.86** between *public* client and *contractors* respondents; and **0.96** between *clients' representatives* and *contractor* organisations (**0.84**; **0.85**; and **0.90** respectively for civil engineering works). Clearly, these statistics show a high association (between any pairs of sample groupings), regarding the use of PSC measured on the particular ranks in both building and civil engineering works (significant at 0.0005 level).

However, the above findings do not show **which** PSC are causing this strong association; or which are considered significantly different from others across the respondents types. The following ANOVA test and multiple comparison analyses were used, to confirm these differences.

Table 6. 3: SRCC Test in Building Works

Organisations Types	*Non-parametric correlation*	*Public Client*	*Private's Representative*	*Contractor*
Public Client	Correlation Coefficient	1.000	-	-
	Sig. (2-tailed)	-	-	-
	N (PC)	32	-	-
Private's Representative	Correlation Coefficient	*.833**	1.000	-
	Sig. (2-tailed)	*.000*	-	-
	N (PC)	32	32	-
Contractor	Correlation Coefficient	*.858**	*.959**	1.000
	Sig. (2-tailed)	*.000*	*.000*	-
	N (PC)	32	32	32

** Correlation is significant at the 0.0005 level (2-tailed).*

Table 6. 4: SRCC Test in Civil Engineering Works

Organisations Types	*Non-parametric correlation*	*Public Client*	*Private's Representative*	*Contractor*
Public Client	Correlation Coefficient	1.000	-	-
	Sig. (2-tailed)	-	-	-
	N (PC)	32	-	-
Private's Representative	Correlation Coefficient	*.838**	1.000	
	Sig. (2-tailed)	*.000*	-	
	N (PC)	32	32	
Contractor	Correlation Coefficient	*.854**	*.895**	1.000
	Sig. (2-tailed)	*.000*	*.000*	-
	N (PC)	32	32	32

** Correlation is significant at the 0.0005 level (2-tailed).*

6.4.2 Tests for Violation Assumption

Parametric and non-parametric procedures were used in statistical analyses for analysing extent of violation (i.e. parametric assumptions) of the surveyed data. It is concluded that if the results from both tests were found not to differ greatly, then it can be assumed that the data have been drawn from a population which did not violate the parametric assumptions (Bryman and Cramer, 1999:p119; Wong *et al.*, 2001b). In addition, the Levene test was also used to test the equal variance assumption of multivariate statistical analyses.

6.4.3 The Levene Tests

The Levene test was used to test the equal variance assumption (Bryman and Cramer, 1999:p145). Table 6.5 shows the Levene test results for PSC in building and civil engineering works. There were *three* PSC both in building and civil engineering works having unequal variance. In building works, these were: *amount of decision-making authority on site* (PSC3); *contractor's familiarity with geographical area* (PSC17); and *communication and transportation- office to job site* (PSC20).

In civil engineering works these were; *amount of decision-making authority on site* (PSC3); *ability to deal with unanticipated problems* (PSC13); and *actual quality achieved to the similar works* (PSC28). The findings reveal that approximately 9% of the overall respondents' LIA opinions to the particular PSC in both building and civil engineering works exhibit unequal variances. This indicates that only a small portion of the survey data has unequal variation in both different sectors of works.

In order to ascertain the extent of these violations of survey data, it is prudent to run both non-parametric and parametric tests for validating the violation effects. If the results from both tests do not differ widely in both non-parametric and parametric tests, it can be concluded that the data have been drawn from a population which does not violate the assumption conditions. To put this another way, the inferences drawn from the tests are robust.

Table 6. 5: Test of Homogeneity of Variances

Test of Homogeneity of Variances	Building			Civil	
	Levene Statistic	*Sig.*		*Levene Statistic*	*Sig.*
PSC1	0.441	0.644	PSC1	0.896	0.415
PSC2	0.291	0.748	*PSC2*	0.155	0.857
PSC3	3.440	***0.036****	***PSC3***	3.606	***0.034****
PSC4	0.065	0.937	*PSC4*	0.719	0.492
PSC5	0.187	0.830	*PSC5*	0.529	0.593
PSC6	0.038	0.963	*PSC6*	0.285	0.753
PSC7	0.195	0.823	*PSC7*	0.447	0.642
PSC8	0.355	0.702	*PSC8*	1.385	0.260
PSC9	0.980	0.379	*PSC9*	0.914	0.408
PSC10	1.967	0.145	*PSC10*	0.230	0.796
PSC11	0.672	0.513	*PSC11*	0.199	0.820
PSC12	1.803	0.170	*PSC12*	1.973	0.149
PSC13	0.292	0.748	***PSC13***	10.582	***0.000****
PSC14	1.121	0.330	*PSC14*	1.356	0.267
PSC15	2.916	0.058	*PSC15*	0.131	0.878
PSC16	1.565	0.214	*PSC16*	0.009	0.991
PSC17	6.422	***0.002****	*PSC17*	0.334	0.717
PSC18	0.965	0.384	*PSC18*	1.999	0.146
PSC19	0.326	0.723	*PSC19*	0.183	0.833
PSC20	3.795	***0.026****	*PSC20*	0.472	0.627
PSC21	0.616	0.542	*PSC21*	0.910	0.409
PSC22	0.030	0.971	*PSC22*	0.330	0.721
PSC23	1.416	0.247	*PSC23*	1.692	0.194
PSC24	0.483	0.618	*PSC24*	0.050	0.951
PSC25	1.771	0.175	*PSC25*	0.701	0.501
PSC26	0.070	0.932	*PSC26*	1.569	0.218
PSC27	1.268	0.286	*PSC27*	0.757	0.474
PSC28	0.508	0.603	***PSC28***	4.736	***0.013****
PSC29	1.063	0.939	*PSC29*	0.178	0.837
PSC30	0.386	0.681	*PSC30*	0.097	0.908
PSC31	1.416	0.247	*PSC31*	2.037	*0.141*
PSC32	1.310	0.274	*PSC32*	0.008	0.992

** Significantly different at 0.05 level*

6.4.4 Non-Parametric and Parametric Tests

Table 6.6 shows the non-parametric and parametric tests for data related to building works. It is interesting to note that, in building works, PSC with significant differences among the sample groupings in the non-parametric test are actually the same as those for the parametric test. These were:

i. condition and availability of equipment (PSC7);

ii. ability to deal with unanticipated problems (PSC13);

iii. contractor's familiarity with local labour (PSC15);

iv. contractor's familiarity with local suppliers (PSC16):

v. relationship with Local Authority (PSC18);

vi. home office location relative to job site location (PSC19); and

vii. actual schedule achieved on similar works (PSC32).

Table 6. 6: Non-Parametric and Parametric Tests in Building Works

ANOVA						*Kruskal-Wallis*		
		Sum of Squares	*Mean*	*F*	*Sig.*		*Chi-Square*	*Sig.*
**PSC7*	Between	7.408	3.704	3.330	*0.040*	**PSC7*	6.612	*0.037*
	Within Groups	119.009	1.112					
**PSC13*	Between	4.604	2.302	5.256	*0.007*	**PSC13*	9.496	*0.009*
	Within Groups	46.862	0.438					
**PSC15*	Between	7.806	3.903	3.899	*0.023*	**PSC15*	6.834	*0.033*
	Within Groups	107.112	1.001					
**PSC16*	Between	11.437	5.718	4.970	*0.009*	**PSC16*	9.438	*0.009*
	Within Groups	123.118	1.151					
**PSC18*	Between	11.530	5.765	5.546	*0.005*	**PSC18*	11.308	*0.004*
	Within Groups	111.236	1.040					
**PSC19*	Between	15.354	7.677	6.816	*0.002*	**PSC19*	12.635	*0.002*
	Within Groups	120.512	1.126					
**PSC32*	Between	6.004	3.002	4.791	*0.010*	**PSC32*	11.258	*0.004*
	Within Groups	67.042	0.627					

Note: All PSC significantly different at 0.05 level.
** PSC constantly matching in both tests.*

In civil engineering works, the results are almost identical. There were five PSC in the non-parametric test and six in the parametric tests being significantly different across the sample groupings. Among these, it was found that the *amount of key personnel for the project* (PSC4); *home office location relative to job site location* (PSC19); *actual quality achieved to the similar works* (PSC28); *experience with specific type of facility* (PSC29); and *actual schedule achieved on similar works* (PSC32) in both tests. However, *ability to deal with unanticipated problems* (PSC13) is the only criterion found significantly different among the respondents in the parametric test (Table 6.7). The detailed results for both tests can be obtained from Appendices G, H1 and H2.

Table 6. 7: Non-Parametric and Parametric Tests in Civil Engineering Works

ANOVA						Kruskal-Wallis		
		Sum of	*Mean*	*F*	*Sig.*		*Chi-Square*	*Sig.*
PSC4	Between Groups	3.029	1.515	3.407	*0.041*	***PSC4***	6.302	*0.043*
	Within Groups	22.674	0.445					
PSC13	Between Groups	2.047	1.023	3.244	*0.047*	***PSC19***	8.286	*0.016*
	Within Groups	16.088	0.315					
PSC19	Between Groups	11.915	5.957	4.723	*0.013*	***PSC28***	11.864	*0.003*
	Within Groups	64.330	1.261					
PSC28	Between Groups	4.019	2.010	6.918	*0.002*	***PSC29***	6.205	*0.045*
	Within Groups	18.833	0.290					
PSC29	Between Groups	2.865	1.432	3.569	*0.035*	***PSC32***	6.950	*0.031*
	Within Groups	20.469	0.401					
PSC32	Between Groups	5.185	2.593	3.593	*0.035*			
	Within Groups	36.795	0.721					

Note: All PSC significantly different at 0.05 level.
** PSC constantly matching in both tests.*

From the above results, it is apparent that the data used in the analysis have little violation upon the power of test statistic, and therefore the data can be assumed to be normally distributed and of equal variance. Having demonstrated that this data is valid for use in parametric analysis, the following analysis used parametric procedures for finding the significant difference in opinions (i.e. LIA) regarding PSC among the respondents.

6.4.5 Interaction Plot

The interactions of PSC and organisation types are plotted in Figures 6.1 and 6.2. The vertical axis represents LIA reported by different organisations and, the horizontal axis represents the 32 variables (PSC). Cursory perusal of the interaction plots, show that the LIA was affected by the organisation type and different PSC used during tender evaluation.

Figure 6. 1: Interaction Plot of LIA for Building Works

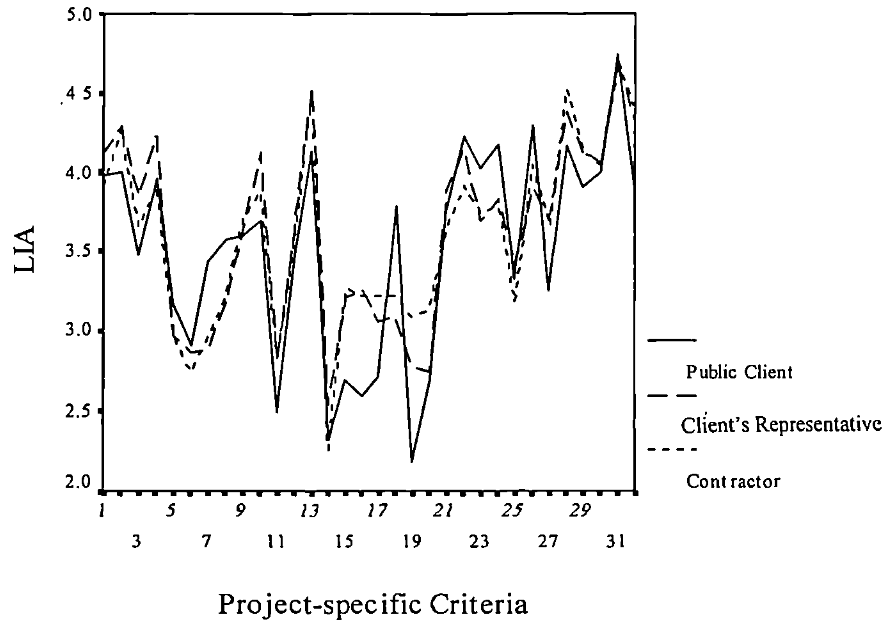
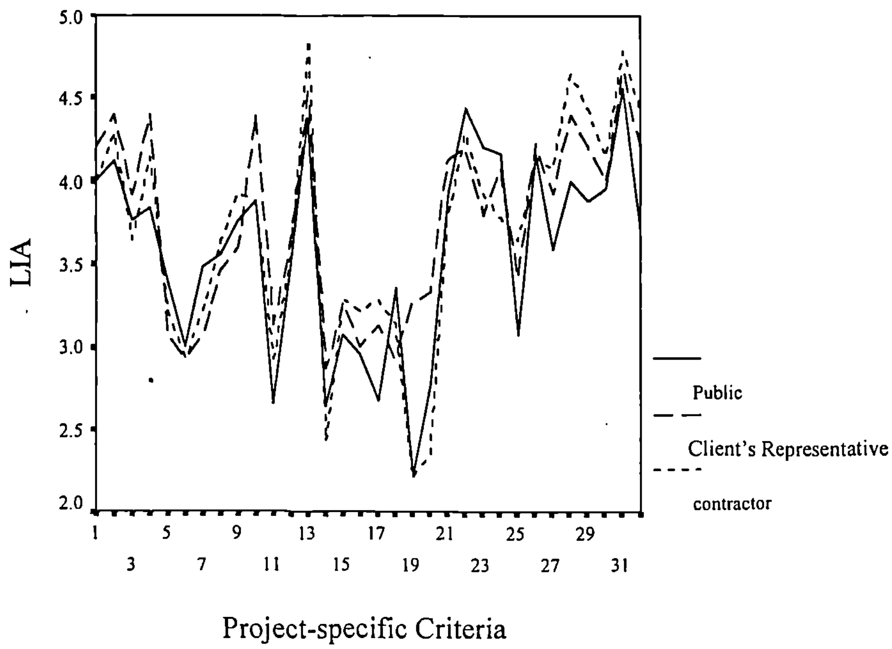


Figure 6. 2: Interaction Plot of LIA for Civil Engineering Works



However, whether these effects are statistically significant can only be determined by testing them via a two-way ANOVA statistical test. The two-way ANOVA confirms whether the population means of LIA are equal for the corresponding PC among the organisation types and, whether there is an interaction between PC and organisation types to give equal or unequal effects on LIA.

6.4.6 Two-way ANOVA

As mentioned in Chapter 5, two-way ANOVA is designed to test differences between the means of variables based upon the *interaction* and *main* effects of two or more factors i.e. independent variables (which account for the variability of LIA means). This analysis is available in SPSS 9.0 in *General Linear Model* (GML) *univariate procedure* (or *Simple Factorial in SPSS version 7.5*). Detailed discussion of *interaction* and *main* effects were presented in Chapter 5.

The outputs of two-way ANOVA for both *main effects* and *interaction effects* in PSC and organisation types for building and civil engineering works are shown in Tables 6.8 and 6.9. Test results in both building and civil engineering works show significant *main effects* of PSC and organisation types ($p<0.0005$, main effects combined). This identifies that the population means of LIA are not equal for all PSC (among the three organisation types), that is, the effects of PSC and organisation types to the LIA were different.

However, the *interaction effects* test of PSC and organisation types upon the LIA mean populations was significantly different ($p<0.05$) in building works, but not in civil engineering works ($p>0.05$). These statistics show that, in building works, LIA depend on organisation types and which PSC used. Therefore, there were *interaction effects* between PSC and organisation types towards the LIA. However, this is not the case in civil engineering works.

Table 6. 8: Two-way ANOVA for PSC in Building Works

			Sum of Squares	**df**	**Mean Square**	**F**	***Sig.***
LIA	**Main Effects**	(Combined)	1061.812	33	32.176	36.727	***.000***
		Organisation Types	8.358	2	4.179	4.77	*.009*
		PC	1053.454	31	33.982	39.788	*.000*
LIA	**2-Way Interactions**	*Organisation Types / PC*	*108.283*	62	*1.747*	*1.994*	*.000*
	Model		1326.746	95	13.966	15.941	*.000*
	Residual		2999.753	3424	.876		
	Totals:		4326.498	3519	1.229		

Table 6. 9: Two-way ANOVA for PSC in Civil Engineering Works

			Sum of Squares	***df***	***Mean Square***	***F***	***Sig.***
LIA	**Main Effects**	(Combined)	542.919	33	16.452	18.621	***.000***
		Organisation Types	8.48	2	4.24	4.799	*.008*
		PC	534.439	31	17.240	19.513	*.000*
LIA	**2-Way Interactions**	Organisation Types / PC	57.432	62	.926	1.048	***.376***
	Model		630.199	95	6.634	7.508	*.000*
	Residual		1441.891	1632	.884		
	Totals:		2072.09	1727	1.200		

To summarise, in building works, respondents viewed PSC differently in LIA attributed those particular criteria, i.e. as to which PSC used and types of organisations. This however was different in civil engineering works, where the effect of type of PSC on the mean of LIA seems to be similar for all organisation types. The following discusses how LIA differences can be observed diagrammatically. The *error bar chart* analysis is used to achieve this objective.

6.4.7 Error Bar Chart

An error bar is centred on the mean of a distribution and extends above and below to show a confidence interval (CI) or a specified number of standard errors or standard deviations (Norusis, 1993:p541). The error bar displays both the central tendency (i.e. mean) and variability of the mean (i.e. lower and upper bounds of the mean variability). The objective is to find out how representative a sample means is, via inspecting the variability of CIs with regard to the population from which the sample was drawn (*ibid.*). Figures 6.3 and 6.4 show the 95% CIs of LIA for client organisations. Public and clients' representatives are combined in this instance, for cross-comparison with contractors' opinions (*see* also section 5.3.8, cross-comparison study of clients and contractors' opinions regarding PC).

These LIA mean populations distributed between the upper and lower bounds of 95% of CI, meaning that it is with 95% confidence that the observed LIA mean populations will fall in into this region. In this instance, the error bar is plotted to compare respondents' opinions regarding LIA means for that particular PSC. Thus, by visually inspecting the error bar patterns, it was found that most of the multiple error bars overlap. The variability of LIA mean populations in both client and contractor organisations can be clearly observed within the upper and lower bounds of bar errors. It is apparent that there is a strong correlation in opinion regarding the use of PSC between clients and contractor respondents. Also, it shows that opinions regarding the use of the PSC in client respondents are very similar to that reported in contractor organisations. This strong correlation was also observed in the earlier SRCC investigation.

Figure 6. 3: Error Bar Chart - LIA Confidence Interval for Building Works

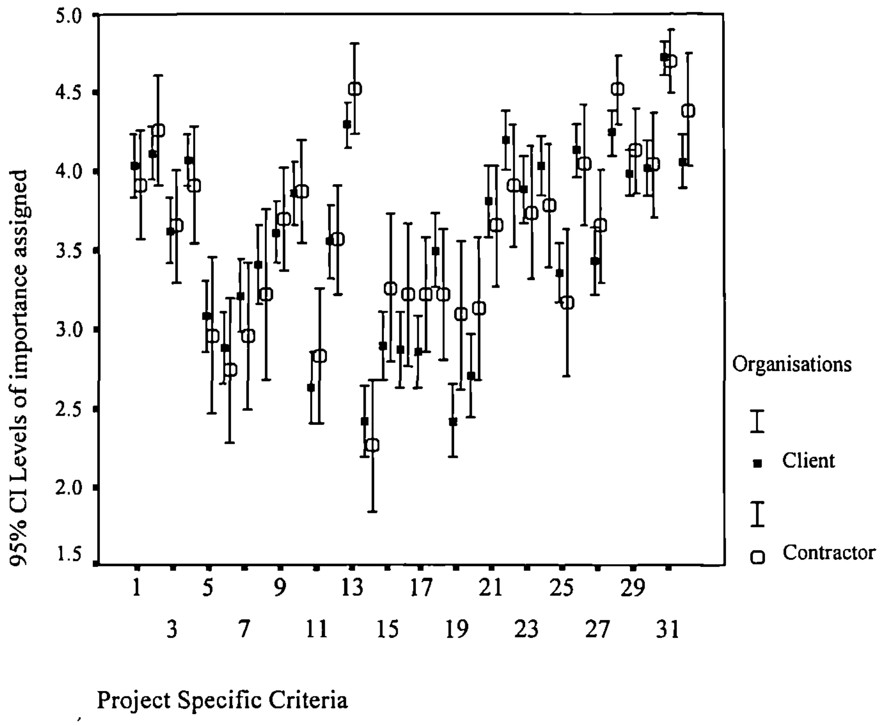
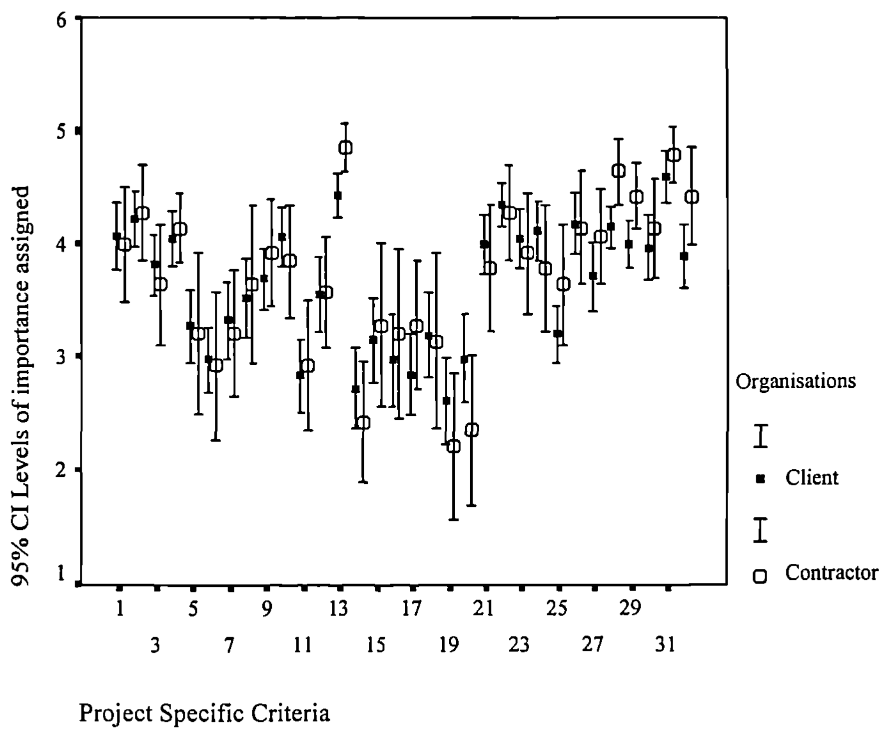


Figure 6. 4: Error Bar Chart - LIA Confidence Interval for Civil Engineering Works



Having discussed the above findings. The post-hoc multiple comparison procedure was used in the following to find the significant differences among the sample groupings in regard to LIA of the PSC.

6.4.8 Investigation of True Differences

One-way ANOVA is used to test a hypotheses about two or more population means, to confirm significant differences of means in two or more sets of variables. But it does not reveal which groups are different from others. In this analysis, for example, it may be that the LIA mean differs for all of the three different types of respondents. Or, it may be that only one or two of the sample groupings differ from others.

Therefore, to pinpoint exactly which sample groupings statistically differ from others, in the LIA in that particular observed PSC, multiple comparison procedures are used to define exactly **where** these differences are. The *Bonfferroni* procedure is used in this analysis. For clarity, Table 6.10 shows those PSC with significant 'true' difference among the respondent groupings. Appendices I and J show the full results of post-hoc multiple comparisons analysis for building and civil engineering works respectively.

Table 6.10 confirms *three* PSC in building works and *one* in civil engineering works statistically different in LIA means among the three sample groupings. Appendices I and J highlight the full details of PSC confident interval figures for both building and civil engineering works.

Table 6. 10: Post Hoc Multiple Comparison: Building and Civil Engineering Works

Building [1]*PSC*		[2]Mean		Mean	[3]*Mean Difference*	*Std. Error*	*Sig.*
PSC13	Client's R.	4.543	Public client	4.125	0.42	0.145	*.014*
PSC18	Public client	3.780	Client's R.	3.086	0.69	0.223	*.007*
PSC19	Contractor	3.087	Public client	2.183	0.90	0.266	*.003*
Civil engineering works [1]*PSC*							
PSC28	Contractor	4.643	Public client	4.000	0.64	0.18	*0.002*

[1] *All PC arranged in the sequence as per Table 6.1 or 6.2 according to the number cited.*
[2] *Highest mean values among the significantly different sample groupings*
[3] *The mean difference is significant at the 0.017 level.*

In building works, clients' representatives viewed *contractor's ability to deal with unanticipated problems* (PSC 13) as being of vital importance and significantly different from public clients. Perhaps this reflects the fact that clients' representatives might consider a contractor to be able to resolve problems and conflicts that might occur (e.g. error or omissions contained in the drawings) without delaying the progress of the construction works, particularly, in complicated and large projects (*refer* Table 5.6 for respondents' workload details).

Public clients placed more emphasis on, and viewed *relationship with local authority* (PSC18) differently than clients' representatives. This relationship is regarded as important by public clients and could be attributed to clients' perception that a good relationship throughout the contract is of vital importance.

A good relationship with the local authority means better communication and reduces the risk of misunderstanding. In many instances, a contractor's good relationship with the local authority is also consistent with familiarity of the geographical area and economic conditions (e.g. supplier and materials). Other reasons may be the fact that public clients may be represented by members of the local authority (Table 5.3).

Response from contractors shows that *home office location in relation to the job site location* (PSC19) is significantly different from public clients. Nevertheless, *home office location in relation to the job site location* gives insight to the speed of decision-making and communication between site and office management as well as to the client, and consultants. According to Holt (1996), being within the project area, a contractor will have a greater understanding of *local economic conditions* (e.g. labour and material suppliers) and *familiarity* of the geographical area.

Findings from civil engineering works show that contractors viewed *actual quality achieved in similar works* (PSC28) significantly different to public clients. One possible reason could be that it points to the fact that good quality performance in previous projects could be seen as able to improve a contractor's reputation, and be linked to company image.

Less PSC were found to be significantly different in civil engineering works (compared to building works) among respondents. This could be attributed to the high correlation in opinions regarding LIA during tender evaluation (i.e. all respondents viewed PSC with equally importance). These can be seen from results obtained from the earlier SRCC and two-ANOVA tests.

6.5 TECHNICAL-ECONOMIC ANALYSIS

Technical-economic analysis is one of the 9 main PSC components, commonly used by construction clients to *revise, analyse* and *compare* all the price-related components and proposed construction methods / procedures made by contractors. The evaluation process for this PSC component consists of:

i. comparison of the client's *estimate* with the *proposed* tender prices;

ii. comparison between *proposed* and *average tender prices*;

iii. comparison of *client's* and *contractors' proposed* direct cost;

iv. review of contractors' proposals i.e. *materials and equipment; unit price and labour cost;* and *time and resources schedule;* and

v. contractor's errors review i.e. as a result of using *erroneous data* or *construction method / procedures.*

One of the advantages of technical-economic analysis is to achieve a rational comparison of tenders submitted by all contractors. It enables identification of uncertainties inherent in the tenders such as contractor's misunderstandings or estimating errors in the proposals. Comparison of *owner's estimates* with *proposed tender prices* is a common practice in the construction industry. According to Gilbreath (1992) it involves the use of a client's prepared estimate as a benchmark for measuring actual tenderer sum during tenderer evaluation; as a means of identifying mistakes or malpractices within tenders.

Comparison *between proposals* and *average tenderer prices* has been widely practiced in many countries (Martinelli, 1986; Ioannou and Leu, 1993). Apart from identification of contractors' estimating errors, it also serves to prohibit the submission of unrealistically low tenders. For instance, the practice of reducing tenderer prices and opportunistic behaviour such as post-contract claims and variations (Crowley and Hancher, 1995).

During the tendering process, it is likely that competitive tendering serves to increase contracting uncertainty arising from estimating error. It poses a serious risk to clients since this can give rise to opportunistic practices such as the pricing of bill items so as to facilitate greater cash benefits in the event of variation (Yizhe and Youjie, 1992; Telchoiz and Ashley, 1978). Therefore, the comparison of: *clients'* and *proposed direct cost; contractors' error* (e.g. *proposed construction methods / procedures*); and *proposal review of unit prices / labour costs / resources* may be able serve to reduce the risk contractors' uncertainties.

The technical-economic analysis is based solely on the measure of average proposed tender sum, price-related factors (e.g. unit price, direct cost, labour costs), and contractors' proposed time and resources schedule. It does not take into account parameters other than these factors. Hence, the uncertainties inherent in the contractors' post tender construction activities (e.g. contractor financial, managerial and technical capabilities) will probably not be greatly reduced via these comparative measures.

The following sections contrast respondents' views (public clients and clients' representatives) of technical-economic analysis. The main objective is to investigate public clients and clients' representatives opinions regarding use of technical-economic evaluation methods, in regard to the different work types observed.

6.5.1 Error Bar Chart

Figures 6.5 and 6.6 show the error bar plots of technical-economic analysis criteria for public clients and clients' representatives, respectively, in building and civil engineering works. There are comparisons of: *owner's estimate with tender price* (PSC33); *proposal and average tender price* (PSC34); *client's and proposed direct cost* (PSC35); *review of proposed in proposed construction method / procedure* (PSC36); and *proposal review* (PSC37). As can be seen, most of the lower and upper bounds regions are close to each other in building works (except PSC37). It is also apparent that 95% CIs of mean scores of each PSC in clients' representatives is higher than public clients, for building and civil engineering works (except PSC36 for building work).

Figure 6. 5: Error Bar Chart - Technical-Economic Analysis Criteria Confidence Interval for Building Works

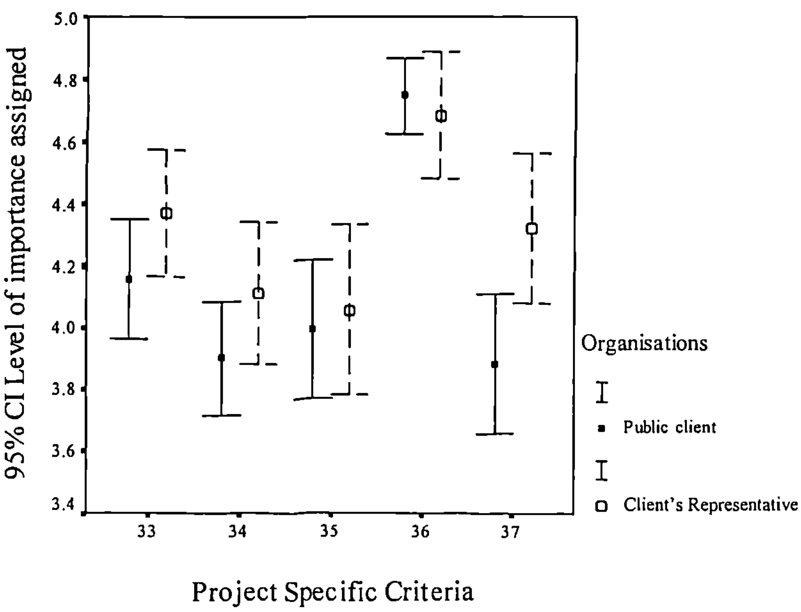
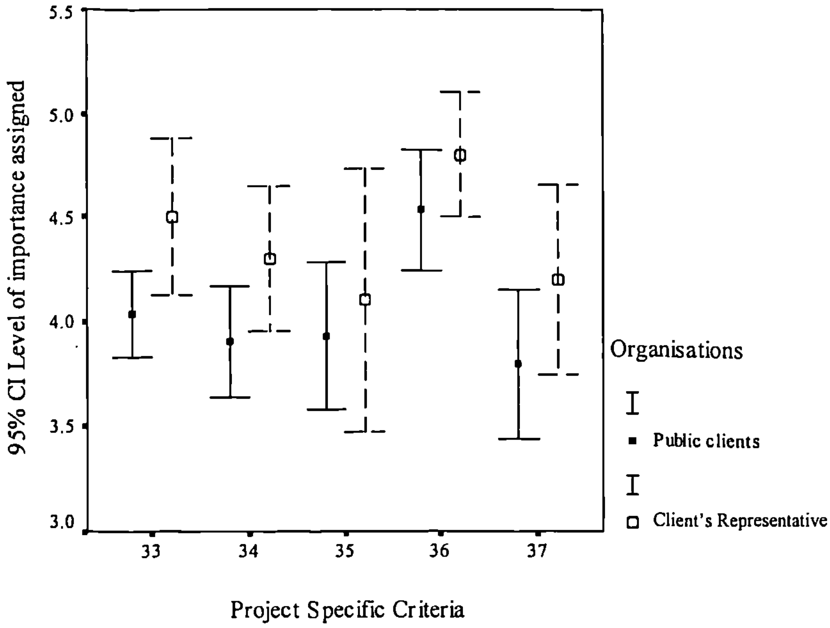


Figure 6. 6: Error Bar Chart - Technical-Economic Analysis Criteria Confidence Interval for Civil Engineering Works



The predominant feature of the above findings is that clients' representatives viewed technical-economic analysis criteria differently to public clients. That is, they placed more emphasis on these criteria compared to public clients. Perhaps from the clients' representatives' perspective, technical-economic analysis criteria give a more thorough comparison of contractors' proposals, rather than just 'lowest-price' selection (discussed later). By this, clients' representatives are able to gain better value for money regarding proposals of the most rational cost, schedule, materials and cost-effective construction methods.

6.6 LOWEST PRICE TENDER

This section discusses the investigation of clients' preferences for lowest tender price selection and comparison of opinions regarding the PSC. The questionnaire asked that respondents considered such preference based upon their past three years' selection experience (Appendix B1, Question-6). To aid insight as to how clients view lowest price selection preferences, the questionnaire presented three different options regarding final evaluation methods:

i. **Option-A**: tender price is the sole basis for tender evaluation and selection of a contractor.
ii. **Option-B**: certain essential criteria (i.e. PSC) have been used in tender evaluation, but selection was still dominated by the principle of acceptance of the lowest tender price.
iii. **Option-C**: tender price was equally as important to those PSC highlighted.

As shown in Table 6.11, a total of 68% of public clients and 67% of clients' representatives chose *Option-B* (i.e. tender price more important than PSC) for building and civil engineering works combined; whilst in *Option-C* (i.e. tender price was of *equal* importance to PSC), there were 22% of public clients and 30% of clients' representatives. *Option-A* (i.e. 'lowest-price wins) was found to have least favour, with only 5% and 3% of public clients and clients' representatives, respectively, basing final selection on tender price alone. From the findings, it seems that public clients are slightly tended to *lowest-price* preference (i.e. 73%, when *Options-A* and *B* combined) compared to clients' representatives (i.e. 70%, *ditto.*).

Figure 6.6 illustrates clients' selection preferences in each category of works for different type of respondents. The 'lowest-price wins' principle i.e. *Option (A)* was far from the best-perceived option. No respondents in respect of civil engineering reported a contract being awarded based on 'lowest-price' alone.

Table 6. 11: Overview of Clients' Preferences in Tender Evaluation

The contractor final evaluation options:

(A) Selection based on lowest tender price
(B) Tender price, but still consider PSC
(C) Tender price and PSC equally importance
(D) No idea / commend

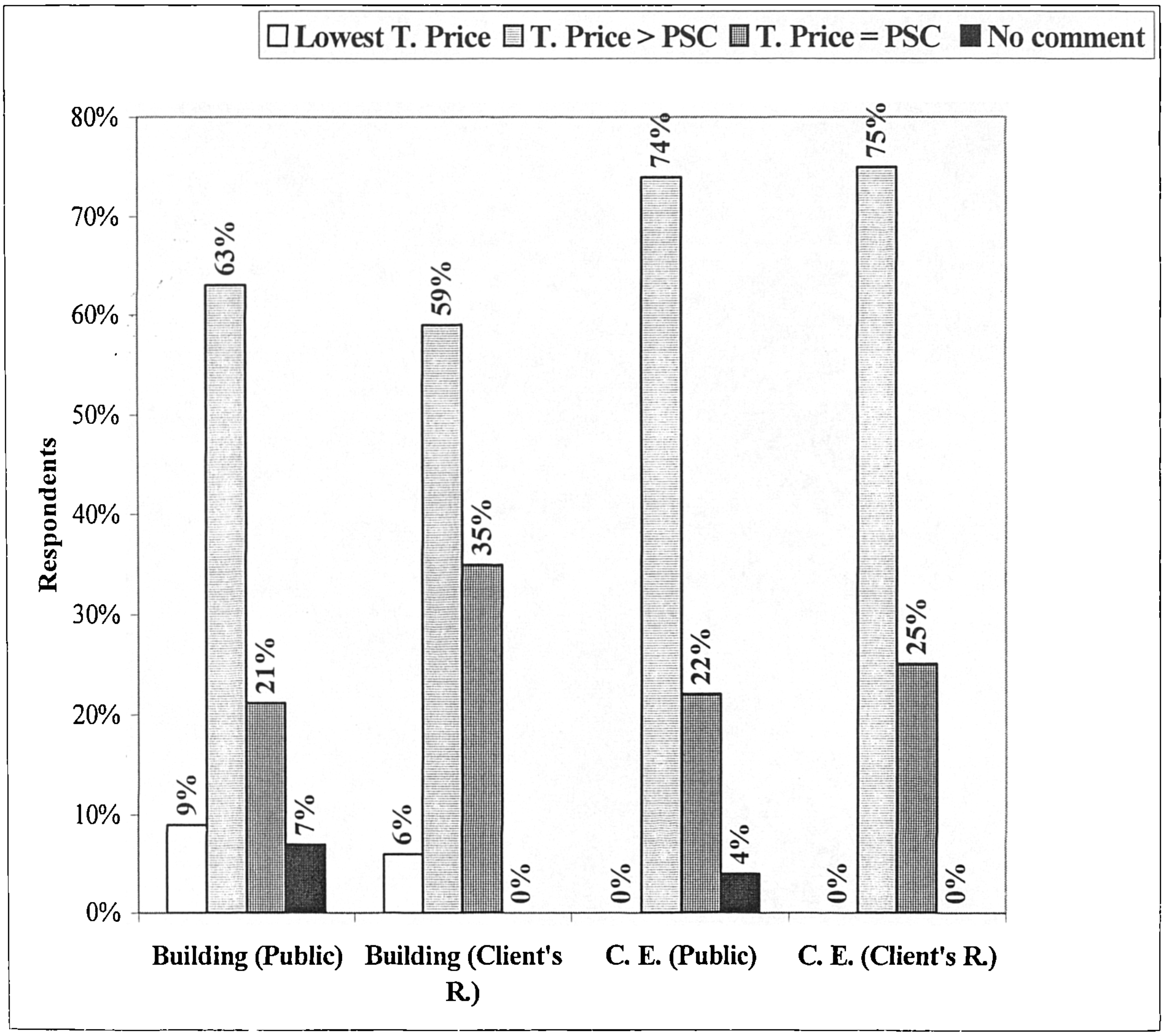
	Public clients Options (110 respondents)			
	(A)	*(B)*	*(C)*	*(D)**
Building (56 nos.)	5	35	12	4
C. Engineering Works (54 nos.)	0	40	12	2
Totals:	*5(5%)*	*75(68%)*	*24(22%)*	*6(5%)*
	Privates' Representatives (102 respondents) Options			
	(A)	*(B)*	*(C)*	*(D)**
Building (54 nos.)	3	32	19	0
C. Engineering Works (48 nos.)	0	36	12	0
Totals:	*3(3%)*	*68(67%)*	*31(30%)*	*0(0%)*

* *Option-D, missing data (who participated the survey but do not offered answer), serves to round up the percentage.*

This may indicate that more *strict* and *close scrutiny* is applied as the nature of work differs away from building construction. It could also be attributed to the use of different types of procurement for these latter work types. *Option (B)* was the most favoured choice in all types of works reported. Comparison between public clients and clients' representatives in *Option (C)* alone, in all types of works shows that clients' representatives placed more emphasis on this option.

Private clients favoured *Option-C* compared to public clients. This reflects different policies and preferences during final evaluation of tenderers. One possible explanation is that clients' representatives preferred a MCS approach in tenderer evaluation more so than the public sector, whereas public sector behaviour could be attributed to the factors cited by Wong *et al.*, (2000b). That is, being too defensive on public scrutiny and criticism (e.g. financial accountability) and deficiencies in public procurement systems (e.g. too rigid, inefficient and unremedied policies).

Figure 6. 7: Clients' Final Selection Preferences in Building and Civil Engineering Works



Combined, the above findings show an increased potential in the use of the MCS approach in tender evaluation. The findings also identify some of the important features which contrast with the earlier findings of Baker and Orsaah (1984), Merna and smith (1990) and Jennings and Holt (1998).

This finding confirms earlier signals for achieving value from various investigations (e.g. CIC, 1993; Holt *et al.*, 1995; CIRIA, 1998). One can sensibly assume that a construction client's fear of lowest-price does not guarantee the overall lowest project cost on completion. Perhaps this is a reflection that best possible 'value' from contractors can only be measured from contractors' attributes (i.e. MSC approach) during tenderer evaluation stages.

The survey evidence also points towards construction clients having been influenced to some extent either by *good guidance documents* and / or *industry commentators* (Chapter 3), that tender price is not the 'optional' choice, but rather, should remain a 'consideration' whilst simultaneously looking for a MCS approach. These influences inevitably encourage construction clients to make an effective transition, such as implement equal preference (i.e. *Option-C*) during tender evaluation.

6.7 SUMMARY

This chapter concentrated on investigation of opinions regarding PSC and the lowest-price selection preferences in UK construction practitioners in building and civil engineering works. The empirical survey results show significant differences in LIA for some of the evaluation criteria among public clients, clients' representatives and contractor organisations in both building and civil engineering works. These PSC are: *contractor's ability to deal with unanticipated problems* (PSC 13); *relationship* *with local authority* (PSC18); *home office location in relation to the job site location* (PSC19); and *actual quality achieved on similar works* (PSC28)

Findings from investigation into the use of PSC and the 'lowest-price wins' principle during evaluation of tendering contractors, reveals that the industry is moving to a more MCS approach (Table 6.11 and Figure 6.7). This shows that choice of contractor is being made on a 'value' rather than 'lowest-price' judgment and is therefore in harmony (to some extent) with the aspirations of CIRIA (1998). This concept has also been cited in Latham (1994) and CIC (1994).

The importance of the two sets of selection preferences (i.e. use of PSC and technical-economic analyses criteria) indicated that the respondents share certain commonalties during tender appraisal processes. It concludes that respondents' decision-making preferences are not specific, but are implied and considerably correlated in some cases.

The next chapter discusses in detail the use of PSC (and their LIA) for developing contractor performance classification models based on a case studies approach. Methodology and techniques for developing the classification models are highlighted, particularly, in the application of the multivariate discriminant technique.

CHAPTER 7

THE DISCRIMINANT ANALYSIS TECHNIQUE

7.0 INTRODUCTION

The main feature of this chapter is to discuss the technique of *multivariate discriminant analysis* (MDA), and particularly, its use in contractor classification research. A literature review of previous studies that have used this method in construction research and the prerequisites for computing a contractor classification model are also focussed upon. Discussion of the MDA technique includes the theory of MDA as a computation process, multivariate analysis assumptions, its advantages in a research setting and the practical application of MDA in computer analysis.

The *project-specific criteria* (PSC) and their respective *levels of importance assigned* (LIA) are used for development of a discriminant function. These are also described in this chapter. Those PSC incorporated within the discriminant models were used as discriminant factors. These PSC are what clients perceived as important during tender evaluation for selection of a 'good' contractor (*refer* Chapter 6).

7.1 THE APPLICATION OF PREDICTIVE MODELS IN TENDER EVALUATION

As explained earlier in this thesis, a good contractor is expected to complete a project on time, within cost, and to the client's desired quality. Unfortunately, this is not always the case; research and case studies have highlighted that clients' satisfaction (or a combination of *time, cost* and *quality* performances) is difficult to achieve (Ward, *et al.*, 1991; Kometa, *et al.*, 1995; Chinyio *et al.*, 1998; Soetanto *et al.*, 1999).

Despite this, finding suitable procurement routes to try and improve clients' 'total' satisfaction have constantly attracted much attention from both industry and the academic world (Banwell, 1964; NEDO, 1985; Skitmore and Marsden; 1988; Turner, 1990; Latham, 1994; Chinyio *et al.*, 1998; Love *et al.*, 1998; Egan, 1998). However, it is still questionable as to whether client satisfaction can be accurately modelled and therefore remains something of a challenge (e.g. Ward, *et al.*, 1991; Poon, 1999;2000).

In recent years, a number of innovative approaches have been designed to achieve the selection of 'good' contractors (Chapter 1). For example: a quantitative assessment of clients' needs and evaluation of contractors' potential (e.g. Tam and Harris 1996; Chinyio *et al.*, 1998); predictive models of construction contractors' performance in aiding clients' decision-making during contractor selection process (e.g. Abidali, 1990; Ng, *et al.*, 1995; Kometa, *et al.*, 1995); and using MDA for evaluating construction materials suppliers risks when furnishing construction contractor credit (e.g. Nicholas *et al.* 2000).

Some of these methods have been designed to provide a quantitative indication of contractors' cost or quality performance using *univariate* statistical methods i.e. one dependent variable and one independent variables (Kinnear and Gray, 1999:147), to find the differences (e.g. tender price, cost, time or past performance of quality) between groups; to attempt quantitative performance classification. For example, the prediction of contractors' cost / time performance has been attempted (Ellis and Herbsman, 1990; Herbsman, 1995). Others have used *multivariate* statistical analysis i.e. one or more dependant variables and several independent variables (Walker, 1989; Abidali, and Harris, 1995; Tam and Harris 1996; Chinyio *et al.*, 1998).

In a univariate selection method, scrutiny placed emphasis on the investigation of contractors' particular performance such as the classification of contractor's cost, time or quality performance. Almost every study cited different performance assessment methods as being the most effective for selection of a 'good' contractor (e.g. Ellis and Herbsman, 1990; Fong, 1990). However, some of these methods have led to the neglect of contractor performance in other aspects. For instance, the evaluation of contractors' managerial capabilities, technical expertise, and health and safety performance. This however has subsequently been widely recognised by industry practitioners and has led to research using various approaches for achieving multi-criteria contractor evaluation methods (Holt, 1998a; Jennings and Holt, 1998; Wong *et al.*, 2001a).

This chapter (and the remaining chapters of this thesis) seeks to redress the balance; by exploring the *univariate* and *multivariate* analysis of contractors' potential to formulate a selection and classification model(s) in assisting clients' decision-making process during tender evaluation. A brief overview and discussion of the above methods is presented in the following sections.

7.1.1 Time / Cost Evaluation Method

In highway construction projects Ellis and Herbsman (1990) proposed a time / cost quantitative method for evaluation of potential contractors. They converted construction time into a definitive cost measure (comparison of proposed tender price) for tender evaluation. In other words, the successful bidder is judged, based on the lowest combination of bid cost and proposed construction time. Herbsman (1995) further surveyed the '*A+B Bidding*' method and found this was particularly useful in US transportation projects. The '*A+B Bidding*' method can be formalised as follows:

$$\mathbf{LCB} = \mathbf{A} + \mathbf{B}\left(\mathbf{RUC}\right)$$

Where, **LCB** = lowest combined bid of bidder;

A = contractors' bid prices (like any other conventional bidding system);

B = the value of time unit (i.e. day, hour, week etc.) to the client; and

RUC = road-user cost (included in part **B**) which is determined by the transportation authorities.

Under this system, each tenderer had to determine their anticipated construction time. During tender evaluation the owner will justify the lowest combined (A+B) tender by using this formula. The philosophy behind this concept has been discussed earlier (Herbsman and Ellis, 1992). According to Herbsman (1995), the *A+B method* or bidding on cost / time has been used for 15 years in US highway construction. A principal objective of the method is to reduce time in construction to minimise inconveniences to the public, which is viewed to be of vital importance on highway projects. The concept has been advocated by several practitioners (Harp, 1990; Transport Research Board, 1991; Herbsman, 1995).

Nevertheless, the consequent use of this method can also be introduced to new building or refurbishment projects where early completion is the major criterion.

7.1.2 Quality Evaluation Method

In Hong Kong and Singapore, public housing construction clients use quality assessment for contractor prequalification and evaluation. Stringent quality control and evaluation are applied to contractors who are seeking continued listing in the register for public sector works and for evaluation of tenders. The *Performance Assessment Scale System* (PASS) of the Hong Kong Housing Authority and *Construction Quality Assessment System* (CONQUAS) in Singapore Housing Development Board (HDB) are used in contractor prequalification and tender evaluation respectively. Both have similar characteristics, in measuring contractors' quality performance. These systems consist of inspecting, measuring and recording the quality performance of contractors. Under the CONQUAS system, the contractor with good scores in quality performance will achieve pricing advantages in tendering for public and HDB projects (Fong, 1990; Housing Authority List of Building Contractors, 1997).

7.1.3 Multi-Attribute Approach

A multidimensional utility approach has been used by many researchers in the context of contractor selection (Diekmann, 1983; Moselhi and Martinnelli, 1990; Holt *et al.*, 1994b). In this method, multiple criteria were identified and weights assigned according to individual importance of the client's needs and the project's objectives. Alternative bids were then given scores with respect to each criterion. These scores were then multiplied by the weights (that have been assigned to respective criteria). The aggregated sum of all the weighted scores represent a contractor's overall score. The contractor receiving the highest score will normally be selected. The shortcomings of this method is that most weights assigned to the criteria rely on individuals' preferences and are a result of subjective judgement.

The aforementioned works illustrate useful approaches to tender evaluation with the results demonstrating some *univariate* analyses (cost / time or quality assessment methods) and multi-criteria evaluation approaches. Nevertheless, the cost / time techniques imply a definite measure for achieving selection of a 'good' contractor. That is, based on contractor's overall cost or quality performance to forecast their potential performance. However, in actual practice, contractor failure (to perform a contract) could be also due to many factors such as: contractor's financial and management capabilities; technical expertise; health and safety; supply chain management, etc. The shortcomings inherent in these studies for evaluation of contractor performance lies therein. The multi-attribute approach, however, is subject to an arbitrary weighting regime with respect to which criteria are 'most important'. Very often, the reliability of this method is subject to individuals' experience and knowledge. The objective of the research in the following chapters is therefore to concentrate on these identified shortfalls.

In order to generate and combine all the factors (contractor attributes) into a reliable predictive model; to evaluate contractors' performance and capabilities more efficiently, a *multivariate* analysis approach was used. Multivariate analysis has the advantage of dealing with the entire variable profile of the object under review simultaneously, rather then sequentially examining its individual characteristics (Altman, 1968).

To achieve the above objectives *multivariate discriminant analysis* (MDA) is applied in this study. MDA is unique, in the sense that a quantitative model (i.e. a linear combination function) is developed to combine the most significant discriminant factors (i.e. contractors' attributes) in classifying contractor performance (e.g. *good* or *poor*). This is done for UK building and civil engineering works (combined); for public clients and clients' representatives combined. In so doing, the investigation of contractors' attributes (or more specifically PSC) can be used as predictive variables when combined into this linear function for classifying contractor performance; which will then classify contractors into distinct categories i.e. *good* and *poor* contractor groupings. The identified independent variables in each linear function indicate the most powerful discriminating factors for separating the groups using multivariate measures (Altman, 1968).

7.2 DISCRIMINANT ANALYSIS IN CONSTRUCTION RELATED RESEARCH

Discriminant analysis is a multivariate analysis of variance (MANOVA) technique used for investigating or grouping cases with similar characteristics, and to identify a mathematical function which in turn exhibits differences among observed groups. To achieve this, a linear discriminant function is developed via maximising the ratio of between-group variation to within-group variation (Kinnear and Gray, 1999:p341-343).

Discriminant analysis was first developed by Fisher (1936), who was searching for a solution to overcome problems in biological and behavioural research. The technique has been widely used in a variety of disciplines since its first introduction in the

1930s. Discriminant analysis is a statistical technique designed to differentiate among several mutually exclusive groups based upon a discrimination function of their observed independent variables (Altman, 1968).

The technique has been widely used for financial ratio analysis to make prediction of company bankruptcy (Altman, 1968;1974; Altman and Loris, 1976). The technique was subsequently used to predict company financial performance by many researchers in Northern America (Deakin, 1972; Johnson, 1970; Blum, 1974). However, according to Abidali (1990) it was not until the 1970s that extensive work using discriminant analysis was carried out within UK construction (e.g. Taffler, 1976;1982;1983;1984;1985; Mason and Harris, 1978; Mensah, 1984).

Use of discriminant analysis has been extended in construction related research since that time (e.g. Mason, 1978; Skitmore and Marsden, 1988; Abidali and Harris, 1995; 1990; Tam and Harris, 1996; Nicholas *et al.,* 2000). However, in the context of construction, most of this research has been applied in bankruptcy prediction or (contractors') creditworthiness analysis. Its application to construction procurement research is less evident (e.g. Skitmore and Marsden, 1988; Salomonsson and Flood, 1990; Tam and Harris, 1996).

Perhaps one possible reason is that this technique is more advanced in nature compared to other statistical procedures (e.g. multiple regression analysis) and requires a substantial amount of calculation for identifying the independent variables found to be significant for use in the discriminant process.

7.3 MULTIVARIATE ANALYSIS AND DISCRIMINANT ANALYSIS

MANOVA is a multivariate extension of ANOVA. The only difference is that there are multiple dependent variables in MANOVA (vis-a-vis ANOVA) (Kinnear and Gray, 1999:p147-148). In MANOVA, the dependent variables are combined into a single variable so that the mean scores of the different groups on this new variable are spread out, or dispersed, to the greatest possible extent. The differences among the group means on the single new dependent variable are then tested by methods similar in rationale to univariate analysis of variance (*ibid.*, *refer* Chapter 5 for ANOVA).

MDA is used in this study to determine the underlying factors that influence contractor performance behaviour. Therefore, the dependent variable used is contractors' performance. The independent variables are the PSC detailed in the following section. The MDA investigates the intrinsic characteristics of PSC and their relationship to contractor performance.

The MDA analysis is mathematically equivalent to MANOVA; the same independent variables are computed with a view to classifying group membership. In this discriminant study, two discriminant functions are developed i.e. Z_1 and Z_2 models. The former classifies contractors into *good* and *poor* groups based on the discriminant factors of contractor's time, cost and quality performances (i.e. exploratory model); the latter is developed to best discriminate contractors into *good* and *poor* groups based on 34 PSC (i.e. main discriminant model). Formation of Z_1 and Z_2 models is detailed in Chapters 8 and 9 respectively.

For brevity and brief introduction of the MDA technique in this analysis, conventional (long hand) calculation and mathematical solutions of MDA are ignored. Rather, this chapter gives a simple paradigm and prerequisites for conducting an MDA, particularly, in concordance with the SPSS version 9.0 package. All essential steps and concepts for the effective use of MDA in this chapter are extracted from the findings and contents from: Fisher (1936), Altman (1968;1993), Klecka (1980), Abidali (1990), Tam (1992), Sharma (1996), and Kinnear and Gray (1999).

To avoid terminological confusion, the term 'discriminant function' denotes the 'canonical discriminant function' and is used through all the following chapters. Other peripheral terms: 'Z score'; 'Z model'; 'discriminant functions; and 'discriminant score' may all be denoted as 'discriminant model'.

7.4 THE ADVANTAGES OF MDA

The MDA technique is a powerful tool for quantitative analysis of data and has the advantages of achieving data **classification** and **identification** of the most influential discriminators (i.e. independent variables). The *classification* computation requires one or more mathematical equations i.e. discriminant functions to allow a user to identify the group which a (previously unknown) case most closely resembles; while the *identification* of discriminators highlights which variables are the most powerful discriminators (Klecka, 1980:p9). The advantages of MDA used in this study can broadly be described as follows:

i. it is a multivariate technique that can consider the entire profile (i.e. level of measurement) of different types of variables / attributes, that give impact on the dependent variable (i.e. contractor's performance behaviour);

ii. it takes into consideration multicollinearity / close interrelationships between independent variables, which can negatively affect multivariate analysis results; and

iii. it is a straightforward function, in the sense that the derived final discriminant factors (variables) profile is statistically significant for determining the relative contribution of each variable to the total discriminating power.

7.5 AIM AND OBJECTIVES OF THE APPLICATION OF MDA IN THIS STUDY

The main aim of using the MDA technique in this study is to derive a linear combination function for *contractor classification* purposes. The objectives of this aspect of analysis include:

i. to identify the variables (PSC) that discriminate 'best' between *good* and *poor* contractors;

ii. to use the identified PSC to develop a discriminant function (and rules) that classifies future observations.

The above can be explored by the use of a discriminant analysis computer programme i.e. SPSS version 9.0. Besides, SPSS also provides the solutions of:

i. testing procedures for discriminant analysis data (e.g. discriminant analysis assumptions);

ii. provision of a variety of types of discrimination computation solutions / options; and

iii. provision of tests of 'goodness of fit' for the developed functions.

The following section discusses how the PSC are measured for computing the discriminant analysis. Details of case studies survey and formation of PSC data are discussed in Chapter 8.

The main task of MDA in contractor classification is to *ascertain* discriminant factors i.e. PSC, that influence contractor performance. To achieve this, 68 case studies of completed projects were investigated, through a postal survey of construction clients (Chapter 8). The surveyed construction clients were asked to classify contractors' performance based on their previous project performance (*good* or *poor*) and in terms of *time, cost,* and *quality* performance (Z_1 model). In Z_2 model analysis, the surveyed clients were then asked which PSC were used and their respective LIA during tender evaluation for the particular project under scrutiny. Based on this information, MDA computed a discriminant function to identify PSC that have significant impact on contractor performance. Therefore, contractor previous (completed) projects performance records and LIA attached to PSC used during the evaluation are vitally important. The following sections detail how these relationships can be used for MDA. The entire discriminant framework and modelling process are discussed in Chapters 8 and 9.

The Z_2 model consists of contractor evaluation criteria i.e. PSC which were measured during the tender evaluation process. The transformed Z score (aggregated magnitude from the discriminant criteria i.e. PSC in that linear function) provides a single readily interpretable measure of contractor's performance, permitting valid cross-sectional performance (*good* or *poor*) classification. Secondly, the most discriminating criteria (i.e. PSC) are shortlisted in the discriminant function. These discriminant factors are statistically distinct from other criteria and therefore represent most important criteria for deciding contractor performance, based on the case study investigations of UK construction projects.

7.6 THE APPLICATION OF MDA AND DISCRIMINANT FACTORS

MDA studies the differences in contractor performance with respect to a number of contractors' attributes, simultaneously, by examining contractors' previous completed projects' performance. To achieve this objective, a structured questionnaire survey was designed, to collect the prerequisite information i.e. PSC used and their LIA from construction clients, during tender evaluation for building and civil engineering projects.

7.6.1 The Z_1 and Z_2 Models

In the Z_1 model analysis, surveyed clients were asked to classify contractor performance into two groups (*good* or *poor*) by consideration of the *overall* outcome. That is, *time, cost* and *quality* performances of the contractor for a particular project (*refer* Appendix K1, Question-8). This was to reveal the client's decision pattern of contractors' performance prior to discriminant analysis. It also allows comparison of the effectiveness of MDA results to the clients' decision patterns i.e. comparison of correctly classified cases (*good* and *poor* as determined by MDA) to the original cases.

To avoid ambiguity, 'fair' and 'satisfactory' performance is grouped into *good* performance. This is to simplify the classification process and for a robust statistical analysis (i.e. to reduce the number of dependent variables to two) so that the investigation will be limited to two classification groups i.e. *good* and *poor*. The independent variables measure of contractor performance in Z_1 model are as follows (*refer* Appendix K1, Questions 5 - 7):

1. Time: the ratio of *actual completed time* to *estimated tender duration.*

$$\text{Time} = \frac{\text{Actual completion time}}{\text{Estimated construction duration in tender}}$$

2. Cost: the ratio of *actual cost* to *estimated contract sum.*

$$\text{Cost} = \frac{\text{Actual cost}}{\text{Estimated cost in tender}}$$

3. Quality: the 1 to 5 Likert scale measures of achieved quality, where:

    1 = poor quality performance compared to the specification;

    2 = slightly poorer than average compared to the specification;

    3 = average compared to specification;

    4 = slightly better than average compared to the specification; and

    5 = good quality compared to specification.

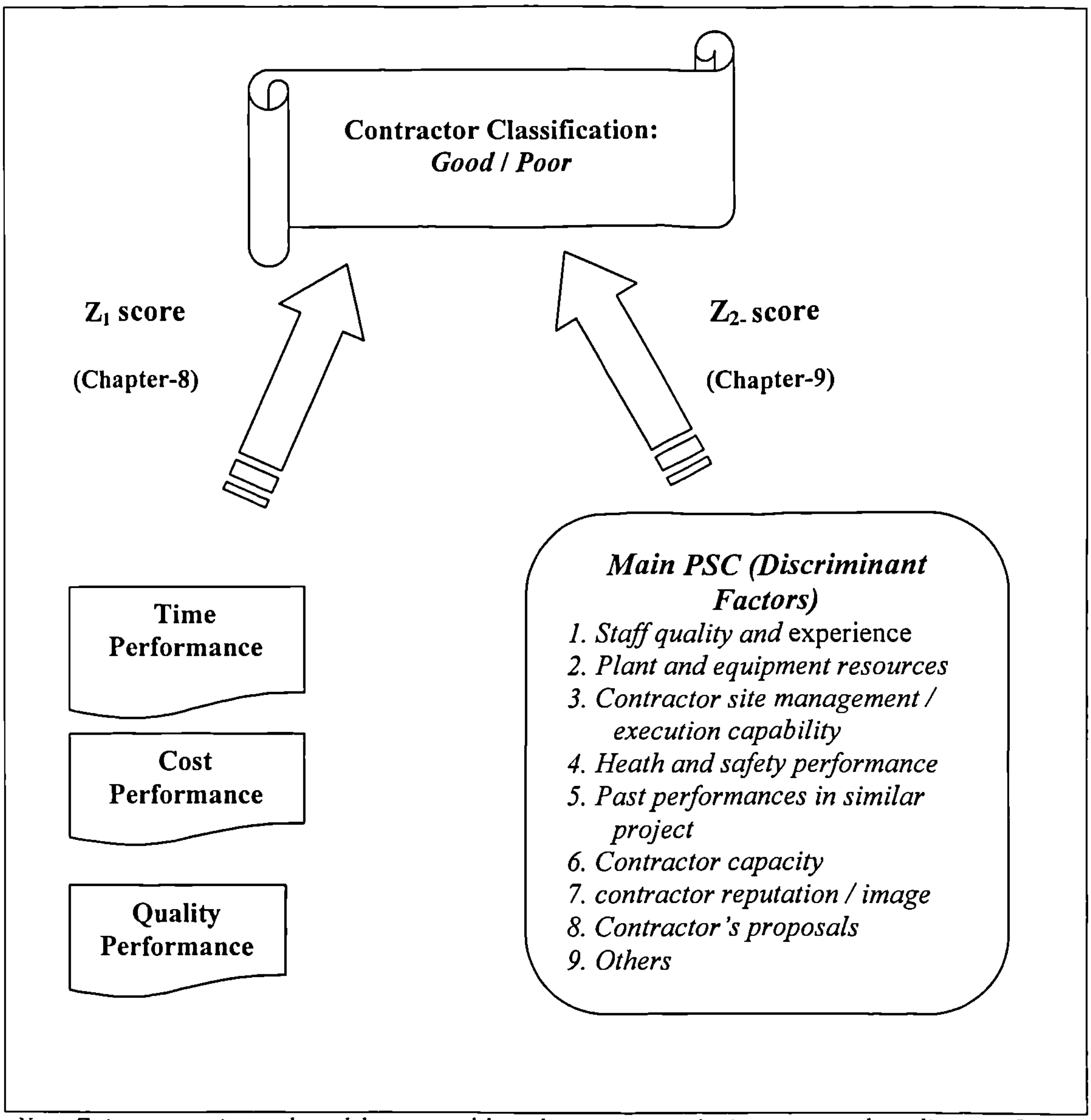
At the outset of this study, *time, cost* and *quality* performances were modelled to deliver a Z_1 score (discriminant function). This Z_1 score is used to demonstrate the effectiveness of classification of the model compared to the original opinions as cited by the respondents (Appendix K1, Question 8).

The next step of this study is vital, that is, to deliver a discriminant function Z_2 score from the data obtained in Component (3) of the questionnaire (refer Appendix K1). The 34 PSC (in Component 3) are used to delineate the differences in contractors' performance. The obtained Z_2 function removed all the PSC that were considered (statistically) insignificant and delivered a set of most important PSC (as perceived by clients and / or client's representative) in deciding contractor performance. Figure 7.1 shows diagrammatically how MDA was applied in this study to achieve the objectives of the research.

7.6.2 PSC in MDA Analysis

Before detailed discussion of the computation of MDA, the next task is to focus on the independent variables (PSC) used and LIA (of the particular PSC) during the course of tender evaluation for construction projects. In determining the possible discriminant factors in the discriminant functions and for achieving a robust discriminant analysis (e.g. avoid multicollinearity effects among the PSC), *thirty-four* PSC were carefully selected from the earlier investigation (Chapter 6).

Figure 7. 1: Computation of MDA and Z_n Scores



Note: Z_1 is an experimental model computed based on contractor's time, cost and quality per; Z_2 is main discriminant model estimated from a set PSC.

Further, to confirm the effectiveness of these PSC in discriminant analysis, previous studies have served as a guidance in this selection (Mustafa and Ruan, 1990; Russell and Jaselskis, 1991; Tam, 1992; Holt *et al.*, 1994b; Hatush and Skitmore, 1997a). The PSC used in discriminant analysis for classifying contractors' project performance are divided into nine main components:

i. staff quality and experience;

ii. plant and equipment resources;

iii. contractor site management / execution capability;

iv. heath and safety performance;

v. past performance in similar projects;

vi. contractor capacity;

vii. contractor reputation / image;

viii. contractors' proposals; and

ix. others.

Each of these is now briefly discussed.

7.6.3 Staff Quality and Experience

Staff quality and experience are a crucial key to a successful project outcome (Mustafa and Ruan, 1990). Training or skill level of craftsmen and the importance of internal training have previously been cited by many (Pilcher, 1992; Moore, 1985a). Holt (1995) proposed four keys areas for measuring contractor's staff quality i.e. (1) *academic qualification*; (2) *membership of a professional Institute*; (3) *age range of the staff*; and (4) *overseas experiences*.

According to Tam (1992), training in management skills is one of the factors in improving contractor's performance in managing projects. Tam further used the ratio of *number of staff taking training* to total *number of staff* for measuring contractor's staff quality.

In this study, three PSC are used to evaluate contractors' staff quality and experience, these are: (1) *staff training programme*; (2) *performance of the project manager(s)*; and (3) *staff quality*. A Likert scale of 1 to 5 is used to measure the LIA of the criteria of (1) and (2); based on a ranked basis i.e. 1 equal to no importance; 3 equal to moderate importance; and 5 for very important. Criterion (3) will be measured via the ratio of *number of professional qualified staff* to *total number of staff*.

7.6.4 Plant and Equipment

Plant and equipment resources are vital in construction activities. The availability and suitability of plant (during tender evaluation) can affect the decision of construction clients in selecting a contractor (Mustafa and Ruan, 1990), and more importantly affect on-site productivity. Two PSC are used to evaluate contractor's plant condition and suitability i.e. *conditions and procedures of contractor's plant management* and *suitability of the plant*. The ownership of plant and construction equipment is not emphasised. One reason is that a vast majority of plant is available for hire as an alternative to ownership in the construction industry. Outsourcing is prevalent in construction, particularly, for plant and equipment (Holt, 1995).

7.6.5 Contractor Site Management / Execution Capability

Evaluation of a contractor's site management and project execution capability were discussed in Bent (1984) and Birrell's (1988) works. Both recognised that tender evaluation should select the 'best' contractor for managing and performing the contract. Bent commented that the potential contractor must provide qualified and skilled staff who has project management responsibilities and execution capability (during construction). Birrell proposed a contractor's past performance evaluation system that contained evaluation of a contractor's capabilities in *cost* and *time* management. In fast-track projects (e.g. cost-plus civil engineering projects), Moore (1985a) discussed the importance of a contractor's project execution during tender evaluation. Moore placed contractor *site-management systems* and *procedures* (e.g. cost, schedule, material control, and safety) as the priority factors for selection of a fast-track projects contractor.

Combined from the above literature findings and results of investigation in Chapter 6, five PSC are considered in this study:

1. type of control and monitoring procedures (proposed);
2. cost control and construction progress systems (proposed);
3. ability to deal with unanticipated problems (i.e. risk management);
4. provision of trained skilled staff / supervisors for that project; and
5. contractor's IT knowledge (e.g. project management software / electronic document management system).

A Likert scale of 1 to 5 is used as level of importance assigned by clients to all these criteria.

7.6.6 Health and Safety

Since the enforcement of Construction Design and Management (CDM) Regulations 1994, health and safety awareness has become much focused in the UK construction industry (Joyce, 1995). A recent UK construction questionnaire survey found that health and safety ranked 2 and 6.5 in public building and civil engineering works respectively (13 and 6 in clients' representatives building and civil engineering works); among the 37 tender evaluation criteria presented (Wong *et al.*, 2000a).

To evaluate a contractor's performance in this aspect, contractors' proposed *health and safety programme,* and *health and safety performances* on previous projects are observed. A Likert scale of 1 to 5 is used to measure these criteria.

7.6.7 Past Performance on Similar Projects

Contractor's past performance can be evaluated and measured in a variety of ways. However, for brevity and easy accessibility to this information (from the respondents via questionnaire survey), contractor's past performance was measured on *time, cost* and *quality* on a similar project, separately. A Likert scale of 1 to 3 (i.e. poor, average and good) was used to measure the contractor's past performance.

7.6.8 Contractor Capacity / Workload

In Holt *et al.*'s, (1994c) investigation, contractor workload ranks highest among the thirty-two variables of the overall ranking. Contractor's capacity was also discussed in Russell and Skibniewski (1990) and Jaleskis and Russell (1992). Both described that the amount of workload for a contractor must be within the contractor's resource constraints prior to the invitation to tender.

Holt (1995) proposed a more detailed analysis of contractor's *Maximum Financial Capacity* (MFC) and *Maximum Financial Outlay* (MFO) for the proposed project for evaluating contractor's current workload. The comparison of MFC and MFO allows for all current forthcoming commitments throughout the duration of the proposed project thus evaluating a contractor's possibility of overtrading. However, in this questionnaire survey, evaluation of a contractor's capacity can be guided by the ratio of *total contract sum in hand* to *the total number of staff*. This method was also used in Tam's (1992) investigation.

7.6.9 Contractor Reputation / Image

During prequalification, contractor reputation and image are considered (*refer* Russell and Skibniewski, 1989). Often, a client feels more 'secure' if a good 'reputation' contractor is employed. Nevertheless, quantification of contractor reputation and image is subjective and difficult to gauge (Tam, 1992). Here, contractor reputation / image is measured by: *origin of the company* (i.e. local or international); *listed on the stock market* (Yes or No); and *years of business in the industry*. Contractor's longevity in business is one of the factors to be considered in contractor evaluation. In essence, it is considered an effective measure of company stability, reliability and experiences in the related industry (Holt, 1995).

7.6.10 Contractor's Proposals

Contractor's proposals (e.g. design alternatives, method statement, and schedules) highlight the possible early involvement of a contractor and contribution of construction expertise in the early design stage (Wong *et al.*, 2000c). Moore (1985a;1985b) placed emphasis on *contractors' proposals* during tender evaluation (for fast track projects). This reveals the consistent growth of client expectation of early project commencement and shorter construction duration. Further, clients may have better alternatives (e.g. contractor proposed construction method and design alternatives) to the proposed project, for achieving their aspirations and needs. The following are criteria proposed in this respect:

i. construction schedules and procedures;
ii. construction methods / statements;
iii. proposed site organisation, work rules, procedures and policies; and
iv. proposed site management and productivity improvement procedures.

All the above criteria are measured on a 1 to 5 Likert scale.

7.6.11 Other Criteria

Other PSC that gave impact to clients' preferences in contractor evaluation are also highlighted. There are eight PSC measured on a Likert scale (1 to 5) for consideration during tender evaluation:

i. contractor's familiarity with weather conditions;
ii. contractor's familiarity with local labour;
iii. contractor's familiarity with local suppliers;
iv. contractor's familiarity with the geographic area;
v. contractor's relationship with the local authority;
vi. home office location to job site location;
vii. communication and transport methods from main office to job site; and
viii. experience with the specific type of construction facility.

The familiarity with *local labour/ suppliers* and *geographic area* considers the strengths, weaknesses and availability of local labour and material supply. *Home office location* and *communication / transport to job site location* are important in terms of speed of decision making between head office and site management (Holt, 1995). *Familiarity of weather conditions* might have some distinct advantages for contractors who carry out long duration construction projects, particularly, in the UK where projects are often hampered by the weather.

7.7 THE COMPUTATION OF MDA: AN OVERVIEW

To clarify the computation of MDA (prior to the real-life exercise in the next chapter), this section discusses how the discriminant function was formed with particular attention to the application of MDA in the SPSS version 9.0 package. However, it is not the intention here to cover in intensive detail MDA computation. The comprehensive elucidation of MDA theory and its mechanism can be obtained from Altman (1968), Klecka (1980); Sharma (1996) and Abidali (1990).

MDA identifies a relationship between independent variables and the dependent variables. Independent variables are selected as being statistically distinct via the maximisation of the ratio of *between-group* (BG) variation relative to *within-group* (WG) variation. To model characteristics of contractor performance (i.e. *time*, *cost*, and *quality* performances) into a single discriminating score, the following formula is used:

$$Z = C_0 + C_1 V_1 + C_2 V_2 + C_3 V_3 + \ldots\ldots + C_n V_n$$

Where, Z = the score of the discriminant function;

C_0 = Constant;

C_n = the coefficients (of V_n); and

V_n = the discriminant variables.

7.7.1 Data Formation

Discriminant analysis begins with selection of cases (case studies) to be included in the analysis. Cases with missing data will be excluded. Particular attention was placed on examination of the interdependencies (correlation) among the variables. Strong correlation i.e. multicollinearity may reduce the efficiency of the MDA model (Klecka, 1980:p9; Mensah, 1984). To remove the influence of multicollinearity, variables that were found to have perfect or strong correlation (i.e. ± 0.95) were removed from the analysis; or combined to form a single variable (Morrison, 1969). The SPSS provides some diagnostic tools for examining the multicollinearity effect.

7.7.2 Selection of Variables in Z_2 Model

Potentially, there were 34 PSC to develop the Z_2 model, but there is no indication as to which would be the best set of variables for forming the discriminant function prior to the discriminant analysis. To compute and generate a combination of PSC found to be statistically significant for the dependent variables (performance behaviour), the process involves eliminating unnecessary (statistically insignificant) independent variables. This process of selecting and removing variables was achieved by using a *stepwise* technique. The statistical procedure for stepwise discriminant analysis is similar to that for stepwise multiple regression.

In the present research, the *Wilk's Lambda* statistic is chosen for the purpose of deciding the addition or removal of a variable during the stepwise processes (i.e. a discriminant measure for selection and elimination of variables). This procedure is available in SPSS 9.0 package. During stepwise selection, a combination of *forward* and *backward* elimination procedures take place. At each stage, a variable is either added or removed. The stepwise procedure starts with *forward* selection, where the variable that is first entered into the discriminant analysis provides the most discrimination power (i.e. those with the lowest Wilk's Lambda) and meets the critical *F* statistic value (i.e. *F* to-enter). In the *backward* elimination, a variable is removed if the *F* statistic does not meet the specified minimum threshold values (i.e. *F* to-remove). The stepwise process will stop when no variable can be added or removed from the discriminant function, to improve its predictive power (Sharma, 1996:p264-265). The significant levels *F*-to-enter and *F* to-remove for selecting and removing independent variables will be discussed in detail later in Chapter 8.

7.7.3 Conditions for Stepwise Selection

The discriminant power of Wilk's Lambda is obtained from an *F* ratio i.e. the ratio of the *within group sum of squares* (SS_W) to the *total sum squares* (SS_T). Wilk's Lambda represents the proportion of the total variance in the discriminant score not explained by differences among groups. In SPSS, the stepwise selection programme requires a variable to be tested by certain minimum conditions and selection criteria. These conditions are the tolerance test (to assure computational accuracy) and the partial *F* statistics i.e. *F*-to-enter / *F*-to-remove, to assure that the increased discrimination exceeds some level determined by cut off values (Sharma, 1996:p264-274).

During the stepwise process, at each step the variable that is included is the one with the smallest Wilk's Lambda. Smallest Wilk's Lambda indicates the minimised SS_W and the maximised SS_T. That is, the minimised WG *sum of squares* (SS_W) and maximised the BG *sum of squares* (SS_B). Thus, it takes into consideration both the difference between groups and the cohesiveness or homogeneity within groups. The calculation of Wilk's Lambda takes the form of:

$$\text{Wilk's Lambda} = \frac{\text{Within group sum of squares}}{\text{Total sum of squares}}$$
$$= \frac{SS_W}{SS_B + SS_W}$$
$$= \frac{SS_W}{SS_T}$$

Therefore, during stepwise selection, a variable that increases homogeneity without changing the separation between the centroids of clusters may be selected over a variable which increases separation without changing the homogeneity. That is, variables that produced the smallest Lambda to be selected in each stepwise procedure.

In the SPSS package, once the process of discriminating i.e. adding and removing is completed, a summary table of the variables remaining in the analysis is listed showing which variables were added or omitted at each step. The variables remaining in the analysis are those used in the discriminant function(s). When more than two groups (multi-group discriminant analysis) are used for classification, the groups may be separated by two or more discriminant functions (Baker and Baker, 1984:p11; Kinnear and Gray, 1999:p343). The first function always provides the best means of predicting membership of the groups; later functions provide further accuracy until changes in predictive accuracy is no longer improved (Kinnear and Gray, 1999:p343). Here, two-groups discriminant analysis was performed thus requiring one discriminant function (see Chapters 8 and 9).

7.7.4 Test for Effectiveness of the Discriminant Analysis Function

To test the effectiveness and accuracy of the derived Z_1 and Z_2 models, the following observations were made:

i. Percentage of cases (contractors) classified correctly: This allows a broad overview of the model's accuracy to be gained and to identify if the model is significantly accurate for classification usage.

ii. The *eigenvalue*: This measures the BG sum of squares and WG sum of squares. The coefficient of the discriminant function are chosen so that BG sum of squares is as large as possible.

$$\text{Eigenvalue} = \frac{SS_{BG}}{SS_{WG}}$$

For achieving a 'good' discriminant function, the larger the *eigenvalue*, the greater the discriminating power (Klecka, 1980:p35; Tam 1992:p80).

iii. *Canonical correlation coefficients*: The canonical correlation coefficient is the measure of association between discriminant score and the group variables. For instance, a value of zero coefficients identifies no relationship between the groups and the discriminant function; large magnitude (always positive) represent increasing degrees of association, with +1.0 being the maximum (*ibid.*, p36-37).

Other methods such as the test for multicollinearity of variables are also particularly important to the accuracy of discrimination power.

7.7.5 Assumptions of MDA

In order to obtain an 'optimal' discriminant function i.e. to provide a 'good' classification model(s), the following assumptions about the MDA data must be met (Klecka, 1980:p9-10):

i. the data must be multivariate with normal distributions ;
ii. there must be equal group population covariance matrices in the data; and
iii. the correlation of variables must not be strong i.e. multicollinearity must be avoided.

Multivariate normality is an important assumption for MDA (Pinches, 1980). This assumption permits the precise computation of the test of significance and probabilities of group membership (Klecka, 1980:p10). However, researchers have realised the 'problems' with gaining data that is statistically perfect. The 'pragmatist' justifies the use of MDA when normality and equal covariance is not entirely satisfied; by applying the derived models to an independent sample and observing the percentage of cases correctly classified (Klecka, 1980; Abidali, 1990:p49-51; Tam, 1992).

The assumptions of (i) and (ii) are not always satisfied in practice. Nevertheless, MDA has been found to be very robust implying that the assumptions need not be strongly adhered to (Joy and Tollesfson, 1969; Deakin, 1977; Abidali, 1990; Nicholas *et al.*, 2000). Besides, MDA can tolerate some deviation from these assumptions (Lanchenbruch, 1975). Lanchenbruch (*ibid.*) found that discriminant analysis is not particularly sensitive to minor violations of the normality assumption. In fact, if large samples are included in discriminant analysis, the test for significance of assumptions of (i) and (ii) can be ignored in many cases (Lanchenbruch, 1975; Klecka, 1984:p61-63). The test for multivariate normality can be obtained in SPSS (optional) features.

In construction procurement research, similar perceptions were also found in Salomonsson and Flood (1990) and Skitmore and Marsden's (1988) works. They used the MDA technique for builders' classification and decision-making in different procurement paths; and found that this technique had been very robust in classifying the variables. Assumption (i) can be tested via observing the distribution of each of the variables individually.

Assumption (ii) is a measure of how much the variables vary together, like a correlation coefficient, the covariance can be tested via statistical procedures in SPSS (i.e. Box's M test) to examine the equality of group covariance matrices. The test is sensitive to departure from multivariate normality. That is, if the normality assumption is violated then the matrices tend to be unequal (Tam, 1992; Norisus, 1995:p72).

In assumption (iii), a *multicollinearity* problem could occur when a high magnitude of correlation exists (i.e. ± 0.95) among any of the variables. It tends to cause serious sample bias and poor classification (Morrison, 1969; Mensah, 1984). Transforming the original data can sometimes overcome this, however this does not always work (Dunteman, 1984:p177). According to Morrison (1968) and Tam (1992:p29), if the independent variables are highly correlated (for estimating the discriminant model), it might be necessary to single out or combine the variables.

7.8 CONCLUSION

The use of MDA in predicting and classification analysis has been proved extremely accurate in previous studies (e.g. Salomonsson and Flood, 1990 and Skitmore and Marsden's, 1988; Nicholas *et al.*, 2000; Wong *et al.*, 2001c). Several practical and theoretical applications of the MDA model have been suggested. The former includes business credit evaluation and investment guidance for observing signs of poor performance (e.g. Altman, 1968;1992; Blum, 1974; Joy and Tollesfson, 1969). The latter has a potential area for future research e.g. the application in construction management related research (other than financial ratio investigation) (e.g. Abidali, 1990, Tam and Harris 1996; Skitmore and Marsden, 1988; Wong *et al.*, 2001c).

The Z_1 and Z_2 models proposed in this study attempt to derive a statistical equation that best classify contractors' performance into *good* and *poor* categories. The developed model will also highlight which PSC are the most important indicators in predicting contractors' performance. MDA has more robust classification power than other methods (e.g. multiple regression analysis) as confirmed in previous studies (Altman, 1968;1993; Abidali and Harris, 1995; Tam and Harris, 1996). To summarise, the advantages of MDA may be outlined as follows:

i. It considers an entire profile of each individuals' characteristics i.e. measures employed to represent each variable;
ii. a single discriminant score is established for distinct performance groupings which contains information regarding how the contractor will perform in relation to the dependent variables.

The following chapters are concerned with the descriptive analysis of the surveyed data and a real life application of MDA in contractor classification.

CHAPTER 8

THE Z_l MODEL: USING CONTRACTORS TIME, COST AND QUALITY PERFORMANCE DATA

8.0 INTRODUCTION

This chapter thoroughly 'explores' the use of the MDA technique for unveiling clients' satisfaction of contractors' performance based on 3 main discriminant factors (i.e. time, cost and quality) with case studies data. The technique is applied to 68 case study (i.e. worked samples) projects as reported by UK construction clients, specifically for this research. The chapter also comprehensively elucidates the mechanics of the MDA (stepwise) technique and highlights prerequisites for yielding the desired outputs.

The developed discriminant model (i.e. Z_l) classified 48 cases (into *good* and *poor* contractor groups) based upon contractors' *time*, *cost* and *quality* performance. The Z_l model demonstrated that 88% of classification was accurate compared to the original classification of contractors' performance. This model was further validated using independent samples, it was found that 70% of the 20 test samples were correctly classified. This shows that the MDA technique is robust for contractor performance classification analysis.

In short, this chapter confirms the effectiveness of MDA and that its mechanism is able to classify, indeed highlight, *good* and *poor* contractors as well as the discriminant factors that are used for developing a MDA model.

8.1 CASE STUDY METHODOLOGY

To further expand and validate the findings from Chapter 6, to a more empirical analysis (with industry real-life practice), a case study approach was chosen for this final stage of investigation.

The objective of the case studies approach is to establish an in-depth investigation of the relationships between clients' evaluation preferences and contractor performance based on real-life data. Therefore, the data for this investigation were from a number of recently completed projects obtained from construction clients. It was also intended by this exercise to respond to the investigation of PSC in Chapter 6. That is, to utilise findings of PSC in Chapter 6 for the contractor classification purpose based on the fact that the MDA technique has an ability to distinguish *good* and *poor* contractor groupings and to highlight a set of 'parsimonious' PSC which statistically (and significantly) contribute to the classification power of the derived model.

Therefore, to investigate the use of PSC in a real life contractor evaluation exercise, the case studies approach was considered appropriate to achieve the objectives of the research.

8.1.1 Questionnaire Design and Contents

A questionnaire survey aimed at collecting the prerequisite MDA data was conducted during the period of June to September 2000. The questionnaire consisted of 3 main components. Component (1) investigated sample characteristics; respondent types; regional classification; and respondents' annual workload. Component (2) was concerned with case studies of actual performance achieved in *time*, *cost*, *quality* and *overall* aspects, for the cases provided (*refer* Appendix K1). In Component (3), tender evaluation criteria i.e. PSC (and their LIA) were investigated, these were criteria thought to affect clients' evaluation aspirations and were used to develop the main MDA model (discussed in Chapter 9). These PSC will serve as independent variables for modelling purposes in relation to the particular projects cited in Component (2).

It is believed that contractor performance in terms of *time*, *cost* and *quality* are multidimensional and that the function of these criteria is concerned with the intrinsic features of distinctive contractor groups (*good* or *poor*). For instance, during tender evaluation, the results of observing such criteria might have vital input for clients' decision-making, and thus for the ultimate success or otherwise, of a project. The MDA in this chapter therefore focused upon the classification of contractors based on these criteria. Details of how the *time, cost* and *quality* performances were measured and used in the MDA were discussed in Chapter 7.

8.1.2 Selection of Sample

A wide variety of building and civil engineering projects, with different types of clients within England, Wales, Northern Ireland and Scotland were incorporated into the case study exercise.

A total of 900 questionnaires were dispatched, targeting 450 questionnaires for public clients and 450 clients' representatives' organisations respectively. These were selected via various construction client lists (*see* Section 4.3.1, Chapter 4 for details). The samples comprised UK public clients, clients' representatives, and consultants.

Public clients were identified from Municipal Year Book 2000- Public Services Directory (Yorke, 2000) and Housing Associations and Directory Yearbook (NFHA, 1998). Clients' representatives and consultant firms were compiled from:

i. The Property Profession Chartered Surveyor Regional Directory (1997).
ii. Housing Associations and Directory Yearbook (NFHA, 1998);
iii. Association of Project Management Yearbook (APM, 1998);
iv. Construction Industry Compendium 2000 (Clayfield and Smart, 2000).

To encourage nation-wide participation and gain widespread distribution of the survey questionnaire, a brief summary of the research was also published in the *Construction News* (i.e. construction industry weekly newspaper) to call upon construction practitioners' to participate in this research (Appendix L).

8.1.3 Analysis of Sample Response

A total of 68 cases were reported from the survey. According to Klecka (1980:p9-10) there is no limit on the number of discriminant factors used in MDA, however the number of cases should exceed the number of variables by more than two. Therefore, the sample size (cases) is adequate to conduct a robust discriminant analysis for producing classification models (discussed later). The case study projects were confined to a 5 years period (from 1996 to 2000) and selected based upon the following criteria:

i. multiple project types: building and civil engineering works including; maintenance, refurbishment and new construction;

ii. different locations: across the UK i.e. England, Northern Ireland, Scotland and Wales; and

iii. a wide range of construction clients from the public clients and clients' representatives.

Comments and feedback were received from a number of respondents including the recommendation for additional PSC to be considered in the MDA model (see Appendices M1 and M2). However, taking into account the need for a 'standard' set of PSC (i.e. 34 PSC as in Component-3) for use in discriminant analysis and the subsequent modelling process, these were not considered in analysis. This precaution was taken so as to avoid an excessive number of PSC which might lead to unpractical models to manage due to the aspect of 'parsimony' in research design (refer Chapter 1, section 1.4.4). Chapter Seven discussed the details of selection and measurement of PSC.

8.2 DESCRIPTIVE ANALYSIS

Of the 68 case reported, 48 were assigned to form Group-A data, and 20 cases to form Group-B data. In this chapter, Group-A was used to form the first MDA model (Z_1 score) based on the independent variables of contractors' *time*, *cost* and *quality* performance. Cases in Group-B are test samples and were used for independent sample tests (i.e. validation). The group sizes and cases chosen for the discriminant analysis in this chapter are shown in Table 8.1.

Table 8. 1: *Good* and *Poor* Contractor Groupings

	[1]*Good* contractors	[1]*Poor* contractors	*Totals:*
[2]Group-A	36(75%)	12(25%)	48(100%)
	Public	*Client's Representative*	
	24(50%)	24(50%)	48(100%)
	[1]*Good* contractors	[1]*Poor* contractors	*Totals:*
[3]Group-B (test group)	11(55%)	9(45%)	20(100%)

[1] *Randomly selected from a total of 68 case studies.*
[2] *Modelling data for Z_I model.*
[3] *Test group for Z_I model.*

8.2.1 Project and Respondent Types

The obtained project types were varied and mainly consisted of building and civil engineering works. Table 8.2 shows the detailed breakdown of the combination for cases in different types of projects and respondents, and in terms of company size. As can be seen from Table 8.2, the majority of cases that are included in this investigation were from England (69%), with others from Northern Ireland (6%), Wales (6%) and Scotland (19%). Under the project type categories, building projects represented a total of 84% from the total cases reported. The remaining 16% were from civil engineering projects. There were three different sizes of respondents classified by annual turnover: *small* (below £5 million); *medium* (£5-50 million); and *large* (above £50 million) organisations; these were 44%, 44% and 12%, respectively, in terms of small, medium and large annual turnover.

One might argue that the sample may not represent the whole population of UK construction clients. However, the main objective of this chapter is the application of MDA to contractor classification analysis, with particular reference to the use of PSC as discussed in Chapter 7. It becomes non-profitable and extremely time consuming if large scale case studies are included in such an analysis.

Table 8. 2: Characteristics of Respondents

	Public (no. of respondent)	Client's R. (no. of respondent)	Totals:
Regional classification:			
England	31	16	47 (69.1%)
Northern Ireland	1	3	4 (5.9%)
Wales	2	2	4 (5.9%)
Scotland	3	10	13 (19.1%)
	37	31	68 (100%)
Project types:			
Building	30	27	57 (83.8%)
Civil Engineering	7	4	11 (16.2%)
	37	31	68 (100%)
Annual turnover / Budget (£ million):			
< £ 5million	12	18	30 (44.1%)
£5m - £50m	19	11	30 (44.1%)
> £ 50m	6	2	8 (11.8%)
	37	31	68 (100%)

8.2.2 Analysis of Contractor's Time, Cost, and Quality Performance

The initial study of contractor classification in this chapter concerns the formation of the Z_1 model. The modelling is based on respondents' data regarding contractors' *time*, *cost* and *quality* performance on the particular projects (cases) that are provided. In this way, the first Z_1 model is able to delineate clients' satisfaction (*good* or *poor*) based on contractors' *time*, *cost*, and *quality* performance on previous projects.

Table 8.3 shows the average (mean) for contractors' performances in *time*, *cost* and *quality* in two distinct categories i.e. *good* and *poor* from the 68 case studies. The table shows *good* contractors overran 1.6% in *time* and 0.6% in *cost* performance; whilst in *poor* contractors these statistics were 42.3% and 23.5%, respectively. In *quality* performance (a Likert scale of 1 to 5 was used), mean values for *good* and *poor* contractor groups were 3.41 and 2.18 respectively. Which means that, *quality* performance in the good group is slightly above average and below average in the poor group.

Table 8. 3: Contractors' Performance in Time, Cost and Quality

	Good contractors (47 cases)	Poor contractors (21 cases)
[1]Time performance	1.016 (1.6% overran)	1.423 (42.3% overran)
[2]Cost performance	1.006 (0.6% overran)	1.235 (23.5% overran)
[3]Quality performance	3.41	2.18

[1] *Measured in the ratio of 'actual completed time' to 'estimated time in tender'.*
[2] *Measured in the ratio of 'actual cost' to 'estimated cost in tender'.*
[3] *Measured in a Likert scale: 1= poor; 3=Moderate; and 5= Good.*

The above results indicate that the *good* group of contractors slightly overran in *time* and *cost* performance. One reason for this is that, in practice, clients' overall satisfaction (time, cost and quality combined) is difficult to accomplish and has to be balanced among these criteria (Ward, *et al.*, 1991, Soetanto *et al.*, 1999). Nevertheless, clients' satisfaction is likely to be higher in the *good* group.

8.3 THE COMPUTATION OF Z_1 MODEL

The first Z_1 model for determining contractors' performance based on time, cost and quality appraisals was derived by a stepwise discriminant analysis. The following sections discuss the discriminant statistics and stepwise computation.

8.3.1 Test of Multicollinearity

Table 8.4 shows test results of within group correlations for time, cost and quality. As can be seen, the correlations are small and imply that multicollinearity does not affect this discriminant analysis. The invert relationship (negative sign of coefficients) between time and quality; and cost and quality performance is due to the different types and invert scales used for measuring contractor performance (i.e. the ratio of time and cost performance; and Likert scale (1 to 5) in quality performance).

Table 8. 4: Pooled Within Groups Matrices

		Time	*Cost*	*Quality*
Correlation	***Time***	1.000	-	-
	Cost	0.257	1.000	-
	Quality	-0.040	-0.131	1.000

8.3.2 Stepwise Discriminant Analysis in SPSS

The output given in Table 8.5 is used to discuss the development of discriminant analysis in SPSS stepwise discrimination procedures. This table shows tolerance levels, significance of *F* statistic and Wilk's Lambda values for each step in stepwise discrimination.

Table 8. 5: Summary of Variables not used in the Analysis

Step		*Tolerance*	*Min. Tolerance*	**F to-enter*	*Wilks' Lambda*
0	Time performance	1.000	1.000	37.730	0.549
	Cost performance	1.000	1.000	4.676	0.906
	Quality performance	1.000	1.000	24.487	0.653
1	Cost performance	0.934	0.934	0.210	0.547
	Quality performance	1.000	1.000	13.018	0.426
2	Cost performance	0.917	0.917	0.001	0.426

** Minimum critical threshold for F to-enter is 3.84 (SPSS default setting).*

The stepwise discriminant analysis begins with comparison of the lowest Wilk's Lambda (or largest *F to-enter* value). In this instance, *time* performance was chosen to enter the function. This variable provides the maximum discrimination as evidenced by lowest Wilk's Lambda (i.e. minimised WG *sum of squares* and maximised BW *sum of squares*) among the 3 criteria (Table 8.5, Step-0) and its respective *F* statistic[1] i.e. 37.730 which is significantly larger than *F to-enter* for evaluating the overall discriminant model ($p<0.0005$, Table 8.6). The value of 37.730 for the *F to-enter* also indicates that the difference between *good* and *poor* groups with respect to the discriminant score is statistically significant. The output gives the significance level of the partial *F statistics* and the tolerance for variables that form the discriminant function as shown in Table 8.6 (i.e. Step-1). In the *backward* (elimination) procedure, if the *F* statistics of any variables does not meet the specified critical minimum threshold values (*F to-remove* 2.71) the variable will be removed from the function. However, this is not the case in this instance, and the *time* performance was not removed at this step (Table 8.7). Therefore the stepwise selection and elimination of Step-1 analysis is completed.

Table 8. 6: Variables Entered / Removed

		Wilks' Lambda							
					Exact *F*				
Step	*Entered*	*Statistic*	*df1*	*df2*	*df3*	*Statistic*	*df1*	*df2*	*Sig.*
1	Time performance	0.549	1	1	46	37.730	1	46	.000
2	Quality performance	0.426	2	1	46	30.303	2	46	.000

Note: At each step, the variable that minimises the overall Wilks' Lambda is entered.

A similar process of stepwise procedures was repeated in Step-2 until there were no further variables with *F* statistics greater than the critical minimum threshold values.

[1] *F*-statistics are use to assure that the increased discrimination exceeds some levels determined by cut off value. It tests the

Table 8.7 shows that after Step-2, none of the variables can be selected / removed into the discriminant function. Consequently, the stepwise discriminant analysis was terminated, with the final discriminant function comprising of *time* and *quality* performances.

Table 8. 7: Variables in the Analysis

Step		Tolerance	*F to Remove	Wilks' Lambda
1	Time performance	1.000	37.730	
2	Time performance	0.998	23.918	0.653
	Quality performance	0.998	13.901	0.549

** Minimum critical threshold for F to remove is 2.71 (SPSS default setting).*

8.3.3 The Derived Z_1 Model

The MDA computes the discriminant coefficients to deliver the Z_1 model. The discriminant function takes the form of:

$$Z = C_0 + C_1 V_1 + C_2 V_2 + C_3 V_3 + \ldots\ldots C_n V_n$$

Where, Z = the score of the discriminant function;

C_0 = Constant;

C_n = the coefficients (of the V_1 to V_n); and

V_n = the discriminant variables (actual values).

The derived (unstandardised) coefficients were used to form the Z_1 model. These unstandardised coefficients multiplied by the original values of the respective variables to derive a Z_1 score. That is, the discriminant model for classification of

significance of increment/decrement discrimination power of the variables for entering/removing to the model.

good and *poor* performing contractors. Table 8.8 shows the derived discriminant coefficients.

Table 8. 8: Discriminant Coefficients of Z_1 Model*

	Unstandardised	*Standardised*	*Index of Relative Importance*
Time performance	3.000	0.778	56 %
Quality performance	-0.825	-0.606	44 %
Constant	-0.881	-	-

* $Z_1 = -0.881 + 3\ (\text{time performance}) - 0.825\ (\text{quality performance})$

The Z_1 model function for time and cost is therefore:

$$Z_1 = -0.881 + 3\ (\text{time performance}) - 0.825\ (\text{quality performance})$$

Where *time* performance is measured as the ratio of *actual completion time* to the *estimated contract duration*, and *quality* performance is measured based on past projects performance represented by:

1 = poor quality performance compared to the specification;

2 = slightly poorer than average compared to the specification;

3 = average compared to specification;

4 = slightly better than average compared to specification; and

5 = good quality compared to specification.

The magnitude of standardised discriminant coefficients is a good index of relative importance. It measures one unit change in the respective variable relative to the similar unit change in other respective variables (Klecka, 1980:p17-29). Thus, standardised coefficients exhibit actual contribution of a variable to the discriminant function. Table 8.8 shows the relative importance i.e. actual contribution of each discriminant factors in descending order of importance of Z_1 model.

However, caution is advised for interpreting standardised coefficients if the presence of severe multicollinearity exists in the data (Sharma, 1996:p254). Sharma (*ibid.*) recommended that the *loadings* or *structure* coefficients for investigating variables' relative importance to the discriminant function can be checked via a *structure matrix* in SPSS 9.0 MDA procedures. The *loading* of a given discriminant variable is simply the correlation coefficient between the discriminant function and the variable without the impact of multicollinearity effect. The closer the *loadings* to ±1; the greater association between discriminant function and the discriminant variable and vice versa. The loadings are given in the *structure matrix* as shown in Table 8.9.

The results obtained from both Tables 8.8 and 8.9 are similar (i.e. order of contribution to Z_1 score), meaning that *time* performance plays an important role in determining contractor performance compared to *quality* performance. Results from the above findings also indicate that the effect of multicollinearity does not exist in the sample data.

Table 8. 9: Structure Matrix

	Function 1	*Order of Contribution to Z_1 scores*
Time performance	0.780	1
Quality performance	-0.629	2
*Cost performance	0.282	3

* *This variable not used in the analysis.*

8.4 TESTS FOR EFFECTIVENESS OF Z_I MODEL

The tests for effectiveness of the discriminant model were described in Chapter 7. The following presents a discussion of test results from *percentage* of cases (correctly) classified, canonical correlation and eigenvalue for validating the derived Z_I score.

8.4.1 Classification Results of the Z_I Model

The proportion or percentage of cases correctly classified is used for justifying the accuracy of the discriminant model (Klecka, 1980:p61-63). Table 8.10 gives the classification results and Z_I scores of Group-A cases. The results of percentage of cases being correctly classified were encouraging. A total of 88% of the cases were accurately classified in Group-A discriminant analysis. Table 8.11 summaries the percentage of *good* and *poor* correctly classified in Z_I model.

8.4.2 The Canonical Correlation

The canonical correlation is a measure of association between the discriminant factors and the discriminant model. Table 8.12 shows the canonical correlation for the derived Z_I model.

The canonical correlation value of 0.76 shows a strong association between the discriminating factors and the derived Z_I function (where perfect association = 1.0). The *square* of the canonical correlation (i.e. r^2) is the ratio of *between groups sum of squares* to the *total sum of squares*. This gives indication of the amount of variability in the discriminant scores attributed to between group difference (Norusis, 1994:p75).

Table 8. 10: Z_1 Model Classification Results and Discriminant Scores: Group-A

PSC from Group-A (48 cases)					[1]Cut off value = 1.3118
Time	*Cost*	*Quality*	*Original*	*Z_1 scores*	*Classification*
1.000	0.932	3	Good	-0.3556	Good
1.000	1.000	3	Good	-0.3556	Good
1.100	1.083	3	Good	-0.0555	Good
1.000	1.500	4	Good	-1.1807	Good
1.000	2.000	3	Good	-0.3556	Good
0.667	0.476	4	Good	-2.1798	Good
0.990	1.111	3	Good	-0.3856	Good
1.067	1.007	3	Good	-0.1545	Good
1.222	1.040	3	Good	0.3105	Good
1.000	1.021	5	Good	-2.0058	Good
1.000	1.000	3	Good	-0.3556	Good
1.000	1.083	5	Good	-2.0058	Good
1.000	1.053	3	Good	-0.3556	Good
1.000	0.759	3	Good	-0.3556	Good
1.000	1.000	3	Good	-0.3556	Good
0.917	1.091	3	Good	-0.6046	Good
0.926	1.002	5	Good	-2.2279	Good
1.333	0.985	5	Good	-1.0067	Good
1.000	0.981	3	Good	-0.3556	Good
1.000	1.000	3	Good	-0.3556	Good
0.889	0.899	3	Good	-0.6886	Good
1.000	1.048	3	Good	-0.3556	Good
1.000	1.143	4	Good	-1.1807	Good
1.047	1.000	4	Good	-1.0397	Good
1.111	1.091	3	Good	-0.0225	Good
1.000	1.000	3	Good	-0.3556	Good
1.056	1.000	3	Good	-0.1875	Good
1.000	1.000	3	Good	-0.3556	Good
1 200	1.300	4	Good	-0.5806	Good
1.125	0.915	3	Good	0.0195	Good
1.000	1.154	3	Good	-0.3556	Good
1.000	0.870	2	Good	0.4696	Good
1.000	1.059	4	Good	-1.1807	Good
1.000	1.000	3	Good	-0.3556	Good
0 857	1.000	5	Good	-2.4349	Good
1 014	1.046	3	Good	-0.3122	Good
2.500	1.024	3	Poor	4.1450	Poor
1.200	1.081	2	Poor	1.0696	[2]Good
2.000	1.429	1	Poor	4.2951	Poor
1.226	1.000	3	Poor	0.3225	[2]Good
1.667	1.800	2	Poor	2.4708	Poor
1.133	1.095	2	Poor	0.8686	[2]Good
1.086	1.064	2	Poor	0.7276	[2]Good
1.000	1.000	2	Poor	0.4696	[2]Good
1.667	1.500	1	Poor	3.2959	Poor
2.000	1.109	3	Poor	2.6448	Poor
2.000	1.404	2	Poor	3.4699	Poor
1 063	1.063	3	Poor	-0.1665	[2]Good

Note: Z = -0.881 + 3 (time performance) - 0.825 (quality performance).

[1] *Refer Table 8.13 for details.*

[2] *Three cases were wrongly classified, therefore 88% (42 48) of Group-A cases correctly classified.*

Table 8. 11: Summary of Classification Results

			Predicted Group Membership		*Total*
		Overall performance	Good	Poor	
Original	**Count**	**Good**	36	0	36
		Poor	6	6	12
	%	**Good**	100	0	100.0
		Poor	50	50	100.0

** 88% of original grouped cases correctly classified.*

Table 8. 12: Summary of Between Groups and Within Groups Variabilities

Function	*Eigenvalue*	*% of Variance*	*Cumulative %*	*Canonical Correlation*
1	1.347	100.0	100.0	.758

Test of Function(s)	*Wilks' Lambda*	*Chi-square*	*df*	*Sig.*
1	0.426	38.387	5	.000

In statistics, correlation is not the same as 'cause'. It provides estimates of covariance, to what extent of two variables are related (Bryman and Cramer, 1999:p178-181). Therefore, a large correlation of 0.76 (Table 8.12) would suggest that the coefficient of determination (r^2) will be 58% ($0.758^2 = 0.575$) of the variability in Z_1 score is accounted by the discriminant factors. The balance of 42% variability might be due to other reasons or variables not included in this discriminant analysis (e.g. health and safety, contractor's design abilities, contractor's capacity, etc.).

Since time, cost and quality have been extensively used for measuring clients' 'total' satisfaction (e.g. Bennett and Hanagan, 1983; Hewitt, 1985; Belassi and Tukel. 1996; Chinyio, *et al.*, 1998; Poon *et al.*, 1999; Ridont, 1999), the estimates of the Z_1 model will concentrate upon these 3 main performance indicators. Detailed investigation using a more comprehensive set of other discriminant factors will be discussed later in Chapter 9. Table 8.12 also shows the percentage of the variance accounted for by the Z_1 function (i.e. eigenvalue) and significant test of the function (i.e. Wilks' Lambda).

8.4.3 The Eigenvalue and Wilks' Lambda

The *eigenvalue* measures the variabilities by the ratio of the *between group sum of squares* to the *within groups sum of squares*, the larger the ratio, the greater the discrimination. As expected, the eigenvalue shown in Table 8.12 is a *non-zero* eigenvalue i.e. 1.347, which is fairly large (Klecka, 1980:p35, Tam 1992:p64). Therefore, the classification is considered good and effective. Since there is only one discriminant function, the eigenvalue of 1.347 of this function contributed one hundred per cent total classification power.

8.5 TEST FOR GOODNESS OF FIT USING INDEPENDENT SAMPLES

The use of discriminant model for classification of observed samples requires external validity for assessing its accuracy and effectiveness (Sharma, 1996:p273). There are many ways to examine the accuracy of a discriminant function e.g. *U*-method, *Bootstrap* method and *Holdout* method. The *U*-method (also recognised as *leaving-one-out* method) was proposed by Lachenbruch (1967), it holds out *one* observation at a time, estimates the discriminant function using the remaining n-1 observations, and classifies the held-out observation. That is, to run n discriminant analyses and classify the n held-out observation. Since the case which is being used for classification is not included in the estimating of the discriminant function, this method gives an almost unbiased misclassification rate (Sharma, 1996:p273-274; Tam, 1992:p136).

In the *Bootstrap* method, the discriminant analysis is conducted on samples being repeatedly drawn from the sample to compute the misclassification rate. The *Bootstrap* procedure requires a longhand calculation to derive the misclassification error and thus needs a considerable amount of time (Sharma, 1996:p274).

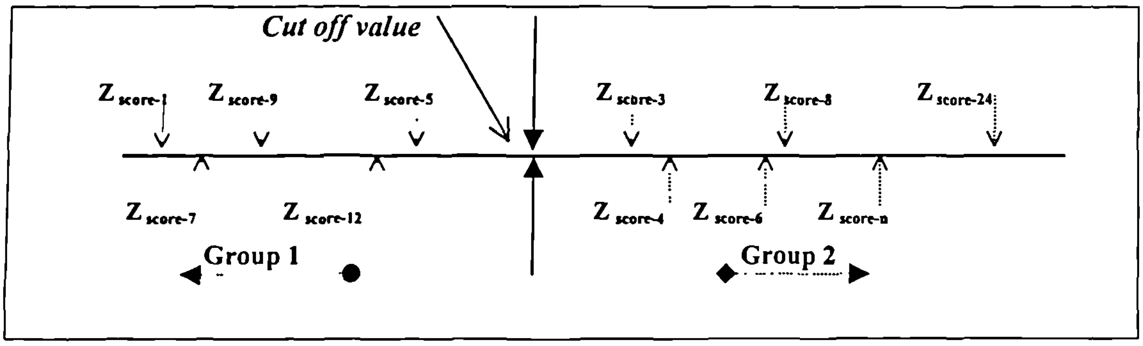
In the *Holdout* method, two groups of a sample are required. The first group is for modelling the discriminant function; the second group for observing the percentage of classification accuracy by inputting the cases into the discriminant function derived from the former group (*ibid.*, p273). This is one of the most common techniques to validate the discriminant function and was adopted in this analysis (e.g. Altman, 1968; Deakin, 1972; Blum, 1974; Abidali, 1990; Tam and Harris, 1995).

In this study, a total of 20 cases (Group-B) were used for assessing the 'goodness of fit' of the derived Z_1 model. Since classification is based on the computed discriminant coefficients from Group-A, computation of these coefficients with new inputted data (cases with actual values) will yield another set of discriminant scores. These discriminant scores will then be justified by a *cut off value*, which gives identification (i.e. percentage of accuracy or misclassification rate) for separating the differences between groups.

8.5.1 The Z_1 Model Cut off Values

In *two-group discriminant analysis* (i.e. classification of contractor performance into *good* and *poor* groups), the classification space is divided into two mutually exclusive and collectively exhaustive regions (Sharma, 1996:p243-244). A definite classification score i.e. cut off value dividing the *one-dimensional* space into two regions (i.e. *good* and *poor* groups in this instance). The objective is to determine a cut off point between groups to minimise the total number of misclassifications by ascertaining the Z score for which contractors cannot be classified as belonging to *good* or *poor* groups (*ibid.*, p254-256). Figure 8.1 shows how the cut off value in a one-dimensional plot distinguishes the differences (discriminant scores) into *good* and *poor* groups. The cut off value is also used for prediction and discriminant classification purposes for future observed cases. However, caution must be taken to avoid two types of error that may occur. That is, *Types I* and *II* errors. In this analysis, *Type I* error is defined as misclassification of *poor* contractors as *good* contractors whilst *Type II* error is the reverse.

Figure 8. 1: Plots of Disciminant Scores and Cut off Value



In SPSS 9.0, the computation of cut off value can be obtained from the summary of discriminant analysis statistics (appears as *Function at Group Centroid*). Table 8.13 shows the cut off values of unequal size groups for Z_1 model. Table 8.14 shows the independent samples test results with the cut off values of 1.3118. The result of using independent samples shows that 70% of the cases were correctly classified (i.e. 14 out of 20 cases). This indicates a good classification power of the Z_1 model.

Table 8. 13: Cut off Values for Z_1 Model

Functions at Group Centroids	
Contractor performance	*Function 1*
Good	-0.6559
Poor	1.9677
**Cut off value*	*1.3118*

**1.3118 = No. of good contractor (1.9677)- No. of poor contractor (-0.6559)*
ΣNo. of good & poor contractor
Refer Hair et al et al., (1998:p265) for the details of unequal cut-off values calculation.

Table 8. 14: Z_1 Model Classification Results Using Group-B Test Samples

PSC from Group-A (48 cases)				[1]Cut off value = 1.3118
Time	*Quality*	*Original*	*Z_1 scores*	*Predicted*
1.200	3	Poor	0.2445	[2]Good
1 000	3	Good	-0.3556	Good
1.200	3	Good	0.2445	Good
1 000	4	Good	-1.1807	Good
1.000	3	Good	-0.3556	Good
1.077	4	Good	-0.9497	Good
1 000	3	Good	-0.3556	Good
1.000	4	Good	-1.1807	Good
1 000	3	Good	-0.3556	Good
1 000	4	Good	-1.1807	Good
1 028	3	Good	-0.2716	Good
1.000	3	Good	-0.3556	Good
1.083	3	Poor	-0.1065	[2]Good
1.400	4	Poor	0.0195	[2]Good
1.000	4	Poor	-1.1807	[2]Good
1.667	1	Poor	3.2959	Poor
1.500	2	Poor	1.9697	Poor
1.200	3	Poor	0.2445	[2]Good
1.500	3	Poor	1.1446	[2]Good
1.525	2	Poor	2.0448	Poor

Note: Z_1 = -0 881 + 3 (time performance) - 0.825 (quality performance).
[1] Refer Table 8 13 for details.
[2] Six cases were wrongly classified, therefore 70% (14/20) of Group-B correctly classified.

8.6 DISCUSSION

The overall classification results show three of the original 48 cases were misclassified. This gave a total of 88% accuracy in cases that had been correctly classified. Thus, the derived Z_1 model is effective in distinguishing between *good* and *poor* performance contractors. The relative importance of the discriminating factors in this model are *time* and *quality* performances which represented 56% and 44% contribution to the discriminant function respectively.

The importance of *time* and *quality* performances in the Z_1 model given by the respondents was also cited in Chapter 6 (i.e. investigation of construction clients' opinion regarding LIA of *time* and *quality* performances in tender evaluation). The output of the findings (i.e. ranking exercise of the aggregated means among 37 PSC) indicates that construction clients in both the public clients and clients' representatives combined gave the highest rank to *contractor ability to complete on time* (Chapter 6, Tables 6.1 and 6.2). In the *quality* performance aspect i.e. *actual quality achieved in previous projects* was ranked an average of 5.5 among 37 PSC, both in building and civil engineering projects combined (*ditto.*). The importance given by respondents to *time* and *quality* performance shares certain commonalities with the survey conducted by Tam (1992). Tam found that *time* and *quality* are two of the most important performance indicators for determining contractor performance.

The matching of the above results indicates that clients' perception of contractors' *time* and *quality* performances is of vital importance for evaluating and selecting a *good* contractor. It shows some commonalities in the use of PSC and their LIA for *contractor evaluation* and *contractor classification*, albeit PSC and LIA being distinctly investigated and analysed differently. For instance, the survey of clients' opinions (Chapter 6) and case study approach used in this chapter. There were some intrinsic links of the results obtained from these two attempts. First, both results show the similar descending order of importance in *time*, and *quality* performances. Second, it underlines the degree of importance of these criteria by construction clients during tender evaluation as well as their decision patterns in classification of the *good* and *poor* contractor groups.

The magnitude and order of importance of *time*, *cost* and *quality* performance are shown in Table 8.8. The results indicate that contractors *time* and *quality* performance have the most significant contribution to the discriminant power. Perhaps these are the most important factors to consider for selecting a *good* contractor. Another possibility is that the respondents' satisfactions in *cost* and *quality* performance were difficult to achieve and have to be precisely stipulated during tender evaluation (Table 8.3).

In conclusion, more importantly, it has been shown that the effectiveness and results of MDA in this analysis were encouraging. Particularly, with the derived discriminant factors and model. The results clearly suggest that the MDA technique can be a robust classification tool for achieving contractor classification and objectives of this research. Therefore, the following Chapter 9 discusses how the MDA technique could be used for developing a main discriminant model i.e. Z_2 model, based on PSC used during tender evaluation.

8.7 SUMMARY

This chapter discussed the use of the MDA technique in analysing clients' satisfaction of contractors' performances in time, cost and quality aspects. Although there were three discriminant factors used in developing the Z1 model, the model was demonstrated to be effective in separating 'good' and 'poor' contractors. For an exploratory analysis such as this, it is interesting to note that stepwise MDA has the ability to highlight these effectively. It is thus believed that MDA techniques can be used in a more rigorous contractor classification analysis. The following chapter discusses in detail the development of the main classification model (i.e. Z_2 model) of this research.

The use of MDA to achieve the objectives of this research was successfully demonstrated. It was observed that the results of MDA were reasonably accurate in contractor classification i.e. 88% accuracy in separating 'good' and poor' contractors, and 70% accuracy in the subsequent independent samples test. Results of applying the Z_1 model are also consistent with Chapter 6 findings, to some extent.

To further expand the subject of contractor classification and use of more comprehensive discriminant factors, Chapter 9 discusses in detail the use of the PSC detailed in Chapter 7, to develop a discriminant model i.e. Z_2 for classifying contractors' performance into *good* and *poor* groups using 34 PSC.

CHAPTER 9

THE Z_2 MODEL: USING PROJECT SPECIFIC CRITERIA DATA

9.0 INTRODUCTION

This chapter discusses the development and results of the main discriminant model (i.e. Z_2 score) for contractor classification and identification of a set of discriminant factors i.e. project-specific criteria (PSC), that can accurately classify contractor performance.

The discriminant analysis mechanics for modelling the Z_2 function are similar to the Z_1 function as described in Chapter 8. Discussion also focused upon the relationships between each discriminant factor, cut off values of the discriminant scores and tests for goodness of fit (with independent samples) of the derived model. The Z_2 model was developed based on the PSC (discussed in Chapter 7) for all types of project (i.e. building and civil engineering works combined) that had been completed by the case study group in the past five years in UK construction (Chapter 8).

9.1 DESCRIPTIVE ANALYSIS

A main discriminant model to classify contractor performance was developed in this chapter. Two sample groupings were used in this multivariate analysis (MDA); Group-A (48 case studies) was used for initial discriminant modelling; and Group-B (20 case studies) formed the test group.

Among the 48 cases in Group-A, 34 cases were 'good' performance contractors and 14 cases were 'poor' contractors, as defined by the projects' clients. There were 11 and 9 cases, respectively, for the 'good' and 'poor' categories in Group-B (Table 9.1).

Table 9. 1: The Case Studies Components

	[1]*Good* contractors	[1]*Poor* contractors	*Totals:*
[2]Group-A	34 (75%)	14 (25%)	48 (100%)
[3]Group-B (test group)	11 (55%)	9 (45%)	20 (100%)

[1]*Randomly selected from a total of 68 case studies.*
[2]*Modelling data for Z_2 model.*
[3]*Test group for Z_2 model.*

9.2 THE DERIVED Z_2 MODEL

Initially, there were 34 independent variables selected for the discriminant analysis (Chapter 7). However, due to insufficient data on *staff quality*, *current workload*, and *project managers' experiences* from the case studies survey, these 3 PSC were excluded from the analysis, thus a total of 31 PSC were used for estimating the Z_2 model. These PSC are shown in Table 9.2. For modelling and cross-referencing purposes, all PSC were assigned a unique identity i.e. from PSC1 to PSC31 (Table 9.2).

9.2.1 The Computation of Z_2 Model

The Z_2 model for determining contractors' overall performance was based on the stepwise discriminant analysis of 48 case studies. The *equality of covariance matrices* and *multicollinearity effects* were observed via Box's M statistics and within-group correlation matrix. Box's M test provides a multivariate test for the homogeneity of the matrices (Norusis, 1994:p72).

Table 9. 2: Contractor Evaluation Criteria for the Proposed Project

Staff Quality and Experience
PSC1. Staff training programme
PSC2. Performance of the project managers
Plant and Equipment
PSC3. Condition and procedures of equipment
PSC4. Suitability of the equipment
Contractor Site Management / Execution Capability
PSC5. Type of control and monitoring procedures
PSC6. Cost control and construction progress reporting systems
PSC7. Ability to deal with unanticipated problems (e.g. risk management)
PSC8. Provision of trained / skilled staff for the particular project
PSC9. IT knowledge e.g. project management software / electronic document management systems
Health and Safety
PSC10. Proposed health and safety programme
PSC11. Health and safety records on previous projects
Past Performance Records in Similar Projects
PSC12. Time, PSC13. Cost, PSC14. Quality
Contractor Reputation / Image
PSC15. Contractor reputation and image
PSC16. Origin of the company
PSC17. Number of years in the business
PSC18. Listed on the stock market
Contractor Proposals
PSC19. Construction schedules and procedures
PSC20. Construction methods / statements
PSC21. Site organisation, works rules / procedures and policies
PSC22. Proposed site management and productivity improvement procedures
PSC23. Proposed tender price
Other Evaluation Criteria
PSC24. Contractor familiarity with weather conditions
PSC25. Contractor familiarity with local labour
PSC26. Contractor familiarity with local suppliers
PSC27. Contractor familiarity with geography area
PSC28. Contractor relationship with local authority
PSC29. Home office location to job site location
PSC30. Communication and transport method from office to job site
PSC31. Experience with specific type of facility

Note: Staff quality, project managers' experience and current workload were excluded from the discriminant analysis due to inadequate response data. Detailed measures for all PSC were discussed in Chapter 7.

Table 9.3 shows the results of equality of covariance matrices. Results show that the null hypothesis can not be rejected (p>0.05) indicating that the covariance matrices are equal.

Table 9.4 shows the result of a multicollinearity test. It was found that correlation among the PSC in Group-A is acceptable for discriminant analysis (multicollinearity< ±0.95, see Morrison (1960) and Tam (1992:p29)).

Table 9. 3: The Equality of Covariance Matrices Test Results

Box's M		23.074
F	Approx.	1.296
	df1	15
	df2	2577.199
	Sig.	***0.196***

Note: Tests null hypothesis of equal population covariance matrices.

9.2.2 Stepwise Procedures for Z_2 Discriminant Analysis

Computation of the Z_2 model started with summary tables of stepwise statistics showing the sequence in which PSC were entered or removed from analysis, along with values of Wilk's Lambda (Table 9.5). The stepwise procedures for modelling Z_2 function are similar to that being discussed in Chapter 8. The procedures begin with the highest *F to-enter* (or lowest Wilk's Lambda) PSC. It is noted that the values of *F to-enter* and *F to-remove* are 3.84 and 2.71. At each step the PSC included in the analysis are shown in Table 9.5. The *F to-enter* (3.84) and *F to-remove* (2.71) are default values used by the SPSS programme. The user can specify any desired level for selecting an 'optimal' number of discriminant factors to be included in a discriminant function(s). According to Klecka (1980:p55-59), the purpose of stepwise selection is to locate a more 'parsimonious' subset of discriminant factors which can discriminant differences between different groups as nearly as possible.

Table 9. 4: Pooled Within Group Correlation Matrix of PSC in Z_2 Model

	PSC1	PSC2	PSC3	PSC4	PSC5	PSC6	PSC7	PSC8	PSC9	PSC10	PSC11	PSC12	PSC13	PSC14	PSC15	PSC16	PSC17	PSC18	PSC19	PSC20	PSC21	PSC22	PSC23	PSC24	PSC25	PSC26	PSC27	PSC28	PSC29	PSC30	PSC31
PSC1	1.000																														
PSC2	0.355	1.000																													
PSC3	0.375	0.243	1.000																												
PSC4	0.374	0.170	0.807	1.000																											
PSC5	0.534	0.389	0.307	0.228	1.000																										
PSC6	0.368	0.361	0.376	0.378	0.617	1.000																									
PSC7	0.429	0.558	0.055	0.152	0.407	0.448	1.000																								
PSC8	0.358	0.471	0.171	0.241	0.548	0.419	0.590	1.000																							
PSC9	0.483	0.304	0.287	0.433	0.417	0.606	0.286	0.326	1.000																						
PSC10	0.165	0.113	-0.022	-0.087	0.197	0.221	0.253	0.134	0.289	1.000																					
PSC11	0.365	0.228	0.046	0.108	0.253	0.054	0.397	0.234	0.285	0.691	1.000																				
PSC12	0.258	0.222	0.125	0.022	0.205	0.161	0.262	0.389	0.284	0.143	0.134	1.000																			
PSC13	0.186	0.136	-0.184	-0.151	0.094	0.068	0.341	0.386	0.182	0.245	0.271	0.314	1.000																		
PSC14	0.301	0.069	0.093	-0.035	0.094	0.033	0.264	0.267	0.123	0.252	0.295	0.599	0.509	1.000																	
PSC15	0.407	0.395	0.329	0.340	0.386	0.498	0.628	0.592	0.445	0.151	0.374	0.398	0.410	0.394	1.000																
PSC16	0.133	-0.054	0.273	0.279	0.151	0.270	-0.161	0.000	0.456	0.023	0.040	-0.036	-0.117	0.096	0.128	1.000															
PSC17	0.079	-0.255	-0.093	0.100	0.023	0.099	-0.089	0.040	0.399	-0.010	-0.030	0.044	0.084	0.066	0.149	0.318	1.000														
PSC18	-0.078	-0.129	-0.191	-0.197	-0.147	-0.250	0.045	-0.001	-0.357	0.065	-0.040	0.078	0.015	-0.107	-0.150	-0.797	-0.133	1.000													
PSC19	0.286	0.217	0.064	-0.030	0.593	0.241	0.309	0.505	0.336	0.135	0.270	0.357	0.190	0.231	0.375	0.212	0.019	-0.097	1.000												
PSC20	0.224	0.223	0.088	0.048	0.424	0.147	0.388	0.561	0.268	0.214	0.250	0.346	0.174	0.271	0.267	0.217	-0.129	-0.074	0.790	1.000											
PSC21	0.366	0.398	0.057	0.004	0.432	0.286	0.425	0.588	0.412	0.446	0.446	0.416	0.446	0.409	0.421	0.167	-0.085	-0.188	0.491	0.594	1.000										
PSC22	0.146	0.440	0.107	0.001	0.374	0.425	0.457	0.409	0.383	0.239	0.238	0.225	0.365	0.086	0.431	0.145	-0.174	-0.208	0.536	0.490	0.494	1.000									
PSC23	0.077	-0.110	0.157	0.118	0.040	0.047	0.042	0.075	0.266	0.011	0.025	0.249	-0.021	0.182	0.169	0.188	0.184	0.016	0.073	0.127	0.122	-0.092	1.000								
PSC24	0.042	-0.330	0.080	0.067	0.003	0.010	-0.156	-0.084	0.068	-0.135	-0.122	-0.061	0.013	0.190	0.059	0.196	0.204	-0.182	-0.042	0.046	-0.151	-0.004	0.179	1.000							
PSC25	0.000	-0.019	-0.226	-0.193	-0.061	-0.100	-0.002	-0.007	0.144	-0.102	-0.097	-0.089	0.245	0.070	0.075	0.100	0.189	-0.208	-0.014	-0.022	-0.031	0.265	0.050	0.585	1.000						
PSC26	-0.027	0.066	-0.293	-0.253	0.037	-0.019	0.107	-0.008	0.085	-0.041	-0.013	-0.049	0.235	0.142	0.134	0.144	0.062	-0.247	0.048	-0.006	0.026	0.302	0.084	0.512	0.878	1.000					
PSC27	0.043	0.044	-0.227	-0.160	0.036	-0.114	0.111	0.117	0.049	0.066	0.042	0.053	0.194	0.293	0.103	0.092	0.126	-0.150	0.046	0.132	0.121	0.072	0.141	0.297	0.613	0.660	1.000				
PSC28	0.006	0.104	-0.142	-0 177	0.151	-0.021	-0.013	-0.095	-0.035	0.115	0.159	-0.232	-0.236	-0.112	-0.106	-0.032	-0.093	0.048	0.061	-0.069	-0.187	0.114	-0.111	0.227	0.377	0.472	0.457	1.000			
PSC29	0.035	-0.239	-0.150	-0.130	-0.033	-0.232	-0.029	-0.124	-0.032	-0.101	0.084	-0.093	0.120	0.013	-0.019	0.213	0.119	-0.153	0.042	0.091	-0.115	0.049	0.217	0.443	0.472	0.436	0.503	0.405	1.000		
PSC30	-0.075	0.090	-0.136	-0.054	0.049	-0.121	0.000	-0.051	0.076	-0.165	0.062	-0.199	-0.072	-0.164	0.012	0.084	-0.013	-0.087	0.166	0.092	-0.147	0.214	0.016	0.441	0.629	0.650	0.372	0.505	0.512	1.000	
PSC31	-0.028	0.268	-0.061	-0.041	0.025	-0.028	-0.027	0.225	0.086	-0.070	0.098	0.023	-0.012	-0.118	0.034	0.197	0.053	-0.237	0.272	0.229	0.129	0.228	-0.095	0.055	0.241	0.259	0.111	0.245	0.287	0.333	1.000

In some cases, too few (or too many) discriminant factors will lead to less accurate classifications (*ibid.*). In this analysis, the default values were used since it achieved the objective of maximising the 'total' discriminant power (the derived discriminant functions i.e. Z_1 and Z_2 scores) and only considered the most significant (parsimonious) PSC. Details of default values (or cut off values) for selection of discriminant factors can be found in Sharma (1996:p265-267) and Costanza and Affifi (1979) works.

Table 9.5 shows variables (with the *F to-enter* value larger than 3.84) that were entered in the analysis from step 1 to step 5. Table 9.6 lists the variables in the analysis at each step from steps 1 to 5 in the *backward* elimination process. It was found that five PSC with value of *F to-remove* greater than the threshold value (i.e. 2.71) were identified and therefore remained in the analysis.

Table 9. 5: Summary of Stepwise Statistics: Variables Entered / Removed*

		Wilks' Lambda							
						Exact *F*			
Step	Entered	Statistic	df1	df2	df3	Statistic	df1	df2	Sig.
1	PSC4	.686	1	1	46	21.013	1	46	.000
2	PSC13	.498	2	1	46	22.691	2	45	.000
3	PSC28	.402	3	1	46	21.802	3	44	.000
4	PSC12	.362	4	1	46	18.955	4	43	.000
5	PSC15	.315	5	1	46	18.301	5	42	.000

At each step, the variable that minimises the overall Wilks' Lambda is entered. Maximum number of steps is 62. Minimum partial **F to-enter is **3.84**. Maximum partial **F to-remove** is **2.71**.*

The *forward* selection and *backward* elimination processes are repeated until step 5, where no further variables have *F value* greater than the critical minimum threshold value of *F to-enter* (3.84) and *F to-remove* (2.71).

Table 9. 6: Variables in the Analysis: Step 1 to 5

Step		Tolerance	F to Remove	Wilks' Lambda
1	PSC4	1.000	21.013	
2	PSC4	.977	19.570	.714
	PSC13	.977	17.042	.686
3	PSC4	.929	22.251	.606
	PSC13	.906	21.391	.598
	PSC28	.898	10.471	.498
4	PSC4	.928	17.479	.509
	PSC13	.837	9.982	.446
	PSC28	.875	11.610	.460
	PSC12	.873	4.787	.402
5	PSC4	.725	25.161	.503
	PSC13	.673	15.813	.433
	PSC28	.853	12.740	.410
	PSC12	.776	7.945	.374
	PSC15	.586	6.313	.362

9.2.3 The Z_2 Model Statistics

Table 9.7 shows results of the Z_2 model statistics. The table shows the total variance accounted for by the Z_2 model (i.e. eigenvalue) and significant test of function (i.e. Wilks' Lambda). Sharma (1996:p284) described that the canonical correlation between the discriminant score and the discriminant factors will lie between +1 and –1, the closer the observed canonical correlation, the more communality there is between the discriminant factors and the discriminant model and vice versa (*refer* Section 8.4.2, Chapter 8). In this instance, the canonical correlation is 0.828 (and its' determination coefficient- r^2, $0.828^2 = 0.686$), which appears considerably high (Klecka, 1980:p37-42; Sharma, 1996:p253; Kinnear and Gray, 1999:p351; Tam, 1992:p211).

Table 9. 7: Statistics of the Z_2 Discriminant Function

Function	*Eigenvalue*	*% of Variance*	*Cumulative %*	*Canonical Correlation*
1	2.179	100.0	100.0	.828
Test of Function(s)	***Wilks' Lambda***	***Chi-square***	***df***	***Sig.***
1	.315	50.306	5	.000

The eignvalue is derived from the ratio of *between group sum of squares* to *within group sum of squares*. The eigenvalue of 2.179 in this instance indicates a good discrimination power of the developed Z_2 model. Wilks' Lambda can be interpreted as a measure of the proportion of total variability not explained by group differences (Norusis, 1994:p75-76). Table 9.7 shows that 31.5% of the observed variability is not explained in this way. The percentage of variance (i.e. 68.5%) accounted for by the Z_2 function was further confirmed by the significant test of Wilk's Lambda in the table ($p<0.0005$).

Table 9.8 shows the unstandardised and standardised discriminant function coefficients of the Z_2 model. The table also tabulates the relative importance of the PSC that contributed the most significant portion of the Z_2 model, in descending order. From the Z_2 model, among the constituent variables, it was found that *suitability of contractors' equipment* contributed the most significant portion for the model, this followed by: *contractor's past performance in cost* (for a similar project); *contractor's relationship with local authority*; *contractor's reputation and image*; and *contractor's past performance in time* (for a similar project).

Table 9. 8: Discriminant Coefficients of Z_2 Model *

	Unstandardised	Standardised	Index of Relative Importance
PSC4- Suitability of the equipment	1.098	0.868	25.6%
PSC13- Past performance in similar project (Cost)	1.328	0.770	22.7%
PSC28- Contractor relationship with local authority	0.500	0.631	18.6%
PSC15- Contractor reputation and image	-0.690	-0.570	16.8%
PSC12- Past performance in similar project (Time)	0.893	0.547	16.2%
Constant	-8.375	-	-

* $Z_2 = -8.375 + 1.098(PSC4) + 1.328(PSC13) + 0.5(PSC28) - 0.690\,(PSC15) + 0.893\,(PSC12)$

9.2.4 The Z_2 Model Prediction

The success rates for prediction of membership of the Z_2 model are shown in Table 9.9. As can be seen, the overall success rate is 90%. The results demonstrate that only 4 out of 48 cases were misclassified. Table 9.10 shows the Z_2 model results and its discriminant scores for Group-A samples.

Table 9. 9: Summary of Z_2 Model Classification Results

			Predicted Group Membership		*Total*
		Overall performance	*Good*	*Poor*	
***Original**	**Count**	**Good**	33	1	34
		Poor	4	10	14
	%	**Good**	97	3	100
		Poor	29	71	100

* 90% *of original grouped cases correctly classified.*

Table 9. 10: Z_2 Model Classification Results and Discriminant Scores: Group-A

PSC from Group-A (48 cases)						[1]Cut off value = -1.537		
Case	*PSC4*	*PSC12*	*PSC13*	*PSC15*	*PSC28*	*Original*	*[2]Z_2 scores*	*Predicted*
1	4	2	2	3	5	Good	0.8874	Good
2	4	2	3	4	5	Good	1.5258	Good
3	4	3	2	4	4	Good	0.5916	Good
4	4	3	3	4	5	Good	2.4191	Good
5	4	2	1	1	5	Good	0.9385	Good
6	3	3	2	4	5	Good	-0.0064	Good
7	3	2	3	4	3	Good	-0.5709	Good
8	3	1	3	3	5	Good	0.2245	Good
9	4	3	3	4	4	Good	1.9195	Good
10	3	2	2	3	5	Good	-0.2102	Good
11	4	3	3	4	3	Good	1.4200	Good
12	5	2	1	3	5	Good	0.6570	Good
13	4	3	3	4	4	Good	1.9195	Good
14	3	3	3	4	5	Good	1.3215	Good
15	5	3	3	5	1	Good	0.8289	Good
16	4	3	3	4	3	Good	1.4200	Good
17	4	2	3	4	4	Good	1.0263	Good
18	3	2	3	3	4	Good	0.6182	Good
19	4	3	2	4	4	Good	0.5916	Good
20	4	3	3	3	3	Good	2.1095	Good
21	4	2	3	4	3	Good	0.5267	Good
22	5	3	2	4	1	Good	0.1905	Good
23	5	3	3	4	4	Good	3.0171	Good
24	4	1	3	3	4	Good	0.8225	Good
25	3	2	2	3	5	Good	-0.2102	Good
26	5	3	3	5	4	Good	2.3276	Good
27	3	3	3	3	2	Good	0.5123	Good
28	4	3	3	4	3	Good	1.4200	Good
29	**2**	**2**	**2**	**3**	**4**	**Good**	**-1.8073**	**[3]Poor**
30	4	3	3	4	3	Good	1.4200	Good
31	4	3	3	4	2	Good	0.9204	Good
32	3	3	3	3	4	Good	1.5114	Good
33	4	3	3	4	4	Good	1.9195	Good
34	1	2	2	2	5	Poor	-1.7159	Poor
35	3	3	3	4	1	Good	-0.6767	Good
36	2	2	2	4	3	Poor	-2.9964	Poor
37	1	2	2	1	1	Poor	-3.0246	Poor
38	**3**	**1**	**2**	**2**	**3**	**Poor**	**-1.4131**	**[3]Good**
39	3	2	2	3	1	Poor	-2.2084	Poor
40	4	1	2	4	3	Poor	-1.6945	Poor
41	2	2	2	4	4	Poor	-2.4969	Poor
42	**4**	**1**	**2**	**3**	**4**	**Poor**	**-0.5054**	**[3]Good**
43	3	1	1	4	4	Poor	-3.6205	Poor
44	3	1	2	3	2	Poor	-2.6021	Poor
45	**2**	**3**	**3**	**5**	**4**	**Poor**	**-0.9652**	**[3]Good**
46	3	2	2	3	1	Poor	-2.2084	Poor
47	3	1	1	3	1	Poor	-4.4296	Poor
48	**3**	**2**	**2**	**3**	**3**	**Poor**	**-1.2093**	**[3]Good**

[1] *Refer Table 9.11 for details.*

[2] $Z_2 = -8.375 + 1.098(PSC4) + 1.328(PSC13) + 0.5(PSC28) - 0.690\ (PSC15) + 0.893\ (PSC12)$

[3] *Three cases were wrongly classified, therefore 90% (43/48) of Group-A correctly classified.*

9.3 TEST FOR GOODNESS OF FIT USING THE TEST SAMPLES

The *holdout* method was used in this study for external validation of the Z_2 model. The independent cases i.e. Group-B test samples were used for assessing the goodness of fit of the derived discriminant models.

9.3.1 Independent Samples Test for Z_2 Model

The derived cut off values (described in Section 8.5.1, Chapter 8) as shown in Table 9.11 can be used to gauge the classification power of the discriminant function for a new classification analysis. Results of the independent samples test are shown in Table 9.12. It was found that 70% of the 20 cases were correctly classified. It demonstrates a satisfactory prediction power of the classification model. This confirms that the Z_2 discriminant function was reasonably precise in classification (prediction) of contractor performance.

Table 9. 11: Cut off Values for Z_2 Model

Functions at Group Centroids	
Contractor performance	*Function 1*
Good	0.927
Poor	-2.252
**Cut off value*	*-1.537*

$$* -1.537 = \frac{\text{No. of good contractor } (-2.252) - \text{No. of poor contractor } (0.927)}{\Sigma \text{No. of good \& poor contractor}}$$

Refer Hair et al et al., (1998:p265) for the details of unequal cut-off values calculation.

9.4 THE Z_2 MODEL HIDDEN PROBLEMS

The results from applying the MDA technique produced a Z_2 model made up of five variables, measuring different aspects of clients' tenderers evaluation preferences.

Table 9. 12: Independent sample Test for Z_2 Model Test Group

PSC from Group-A (20 cases)					[1]Cut off value = -1.537		
PSC4	*PSC12*	*PSC13*	*PSC15*	*PSC28*	*Original*	*[2]Z_2 scores*	*Predicted*
3	**2**	**2**	**3**	**1**	**Good**	**-2.208**	**[3]Poor**
4	2	2	4	4	Good	-0.302	Good
4	2	2	4	3	Good	-0.801	Good
5	3	2	4	4	Good	1.689	Good
4	3	3	3	5	Good	3.109	Good
3	2	2	3	4	Good	-0.710	Good
3	3	3	5	4	Good	0.132	Good
3	2	2	3	4	Good	-0.710	Good
1	**3**	**3**	**4**	**1**	**Good**	**-2.872**	**[3]Poor**
4	2	2	4	4	Good	-0.302	Good
3	3	3	3	5	Good	2.011	Good
2	2	2	2	2	Poor	-2.117	Poor
3	2	2	3	2	Poor	-1.709	Poor
4	**2**	**2**	**4**	**3**	**Poor**	**-0.801**	**[3]Good**
3	2	1	4	3	Poor	-3.227	Poor
1	1	1	4	4	Poor	-5.816	Poor
4	**2**	**2**	**4**	**4**	**Poor**	**-0.302**	**[3]Good**
3	**2**	**2**	**3**	**4**	**Poor**	**-0.710**	**[3]Good**
3	2	2	3	1	Poor	-2.208	Poor
3	**2**	**2**	**3**	**3**	**Poor**	**-1.209**	**[3]Good**

[1] *Refer Table 9.11 for details.*

[2] $Z_2 = -8.375 + 1.098(PSC4) + 1.328(PSC13) + 0.5(PSC28) - 0.690\ (PSC15) + 0.893\ (PSC12)$

[3] *6 cases were wrongly classified, therefore 70% (14/20) of Group-B correctly classified. .*

The accuracies of the classification results in Group-A data (i.e. 90% correctly classified) and the subsequent validation in Group-B cases (i.e. 70% correctly classified) show that the developed Z_2 model was good. However, there are caveats with the model in the present research. For instance, the developed model(s) does not include a specific 'grey area' or 'zone of ignorance' where a range of Z score misclassifications can be observed. Within this 'grey area' two types of errors can occur i.e. Type I and Type II errors (*refer* Section 8.5.1, Chapter 8 for details). This 'grey area' explains how observed cases are susceptible to error classification (i.e. to be misclassified) by the developed model. The limits of the 'grey area' can be set by the user of the model according to the differences in probabilities of 'good' and 'poor' groups. A detailed account of this 'grey area' can be found in Altman (1968), Mason (1978) and Abidali (1980:p109-110).

Also worthy of consideration is the prior probability of the Z_2 model data. By classifying a case into the closest group according to its Z_2 score, results in assigning it to the group for which it has the highest probability of belonging. However, in reality, some cases may actually have a high probability of 'belonging to' more than one group or to none of the groups (Klecka, 1980:p45-46). Table 9.13 shows the five unique misclassified cases from Group-A and their prior probabilities. The probabilities for case 42 are equal for both *good* and *poor* groups, but was classified as within the *good* group. Whilst for cases 38, 45 and 48 have high probability of 'belonging to' the *good* group and were identified as *poor* contractors by the respondents and vice versa in case 29. This infers that there were some uncertainties in the observed cases that the Z_2 model could not explain due to the prior probability 'errors' of the observed cases.

These issues (i.e. 'grey area' and prior probability statistics) do not detract from the usefulness of the Z_2 model, but suggest a level of precaution should be taken when considering the observed data and Z_2 scores.

To summarise, the Z_2 scores are able to indicate contractors that have a profile of poor performance and thus a high probability of failure. Therefore, 'prediction' of contractor (poor) performance using the discriminant model is possible, if the probability of a contractor actually failing when it is classified in the poor performance group is calculated.

Table 9. 13: Prior Probability in Group-A Data

Case	*Z_2 scores*	*Original membership*	*Estimated Prior Probabilities from Z_2 Model for Good Group*	*Estimated Prior Probabilities from Z_2 Model for Poor Group*	*Predicted*
1	0.8874	Good	1.00	0.00	Good
2	1.5258	Good	1.00	0.00	Good
3	0.5916	Good	0.99	0.01	Good
4	2.4191	Good	1.00	0.00	Good
5	0.9385	Good	1.00	0.00	Good
6	-0.0064	Good	0.95	0.05	Good
7	-0.5709	Good	0.77	0.24	Good
8	0.2245	Good	0.98	0.02	Good
9	1.9195	Good	1.00	0.00	Good
10	-0.2102	Good	0.91	0.09	Good
11	1.4200	Good	1.00	0.00	Good
12	0.6570	Good	0.99	0.01	Good
13	1.9195	Good	1.00	0.00	Good
14	1.3215	Good	1.00	0.00	Good
15	0.8289	Good	1.00	0.00	Good
16	1.4200	Good	1.00	0.00	Good
17	1.0263	Good	1.00	0.00	Good
18	0.6182	Good	0.99	0.01	Good
19	0.5916	Good	0.99	0.01	Good
20	2.1095	Good	1.00	0.00	Good
21	0.5267	Good	0.99	0.01	Good
22	0.1905	Good	0.97	0.03	Good
23	3.0171	Good	1.00	0.00	Good
24	0.8225	Good	1.00	0.00	Good
25	-0.2102	Good	0.91	0.09	Good
26	2.3276	Good	1.00	0.00	Good
27	0.5123	Good	0.99	0.01	Good
28	1.4200	Good	1.00	0.00	Good
29	**-1.8073**	**Good**	**0.06**	**0.94**	**[1]Poor**
30	1.4200	Good	1.00	0.00	Good
31	0.9204	Good	1.00	0.00	Good
32	1.5114	Good	1.00	0.00	Good
33	1.9195	Good	1.00	0.00	Good
34	-1.7159	Poor	0.08	0.92	Poor
35	-0.6767	Good	0.70	0.30	Good
36	-2.9964	Poor	0.00	1.00	Poor
37	-3.0246	Poor	0.00	1.00	Poor
38	**-1.4131**	**Poor**	**0.82**	**0.18**	**[1]Poor**
39	-2.2084	Poor	0.02	0.98	Poor
40	-1.6945	Poor	0.08	0.92	Poor
41	-2.4969	Poor	0.01	0.99	Poor
42	**-0.5054**	**Poor**	**0.50**	**0.50**	**[1]Good**
43	-3.6205	Poor	0.00	1.00	Poor
44	-2.6021	Poor	0.01	1.00	Poor
45	**-0.9652**	**Poor**	**0.52**	**0.48**	**[1]Poor**
46	-2.2084	Poor	0.02	0.98	Poor
47	-4.4296	Poor	0.00	1.00	Poor
48	**-1.2093**	**Poor**	**0.70**	**0.30**	**[1]Poor**

[1] *Cases misclassified*

9.5 IMPROVEMENTS TO THE DISCRIMINANT MODEL

The foregoing has identified two statistical errors that have been ignored in the Z_1 and Z_2 models. The following section considers other factors that may cause bias and presents suggestions for further improvement of the developed models.

9.5.1 Random Sampling

The discriminant factor *'Contractor relationship with local authority'* (PSC28) identified as one of the five discriminant factors in the Z_2 model, implies that the model maybe more 'suitable' for use in public sector projects. However, this could be attributed to uncertainties that could not be explained by the model or the data itself. To investigate this bias, an investigation of the observed Group-A data was undertaken for the Z_2 model. A telephone interview was made to all the 48 respondents of the main survey (during February 2001 to April 2001) to re-confirm the accuracy of information given for estimating the Z_2 model.

Results of these follow-up interviews revealed of the 24 clients' representatives, nine had worked very closely with the local authorities in the case studies provided, often acting as their representatives in decision-making during tenderers evaluation. That is, these nine cases were in fact public projects undertaken by clients' representatives. These projects consisted of: National Health Service (NHS) projects; Housing Association projects; and local authorities repair / maintenance works and other term-contracts.

Table 9.14 shows a comparison of the cases study data adjusted to reflect this new information. The actual number of 'private' case study projects fell approximately

19%, meaning that the Z_2 model was developed based mainly on data from public clients (i.e. 69%). This could be one of the reasons why *'Contractor relationship with local authority'* (PSC28) was identified as one of the important discriminant factors in the Z_2 model.

Table 9. 14: Revised Group- A Data

[1]Group-A (Jun.-Sept. 2000)			[1]Group-A (Revised, Feb. – Apr. 2001)		
Public	*Client's R.*	*Total*	*Public*	*Client's R.*	*Total*
24(50%)	24(50%)	48(100%)	33(69%)	15(31%)	48(100%)

[1] *Data for modelling Z_2 functions.*

9.5.2 Historical Data

The collection of historical data is key to improving the effectiveness of any discriminant model. Evidence shows that accuracy in prediction relies on the parameters set for the original data and independent variables that are used for estimating the discriminant model. For instance, in order to develop a model for classifying contractor performance in building refurbishment projects; data (samples) for modelling should come from this particular domain; if a truly accurate discriminant model for predicting contractor performance on such project is to be developed. Therefore, collection of accurate historical data is one of the key factors for improving contractor classification models in the research. Impact of historical data (i.e. sample bias) was also discussed in section 9.5.1.

9.5.3 Lead Time

Another possible factor to be considered is that, accuracy in prediction diminishes as lead-time increases. That is, the duration (i.e. gap) between collection of initial data and the subsequent new cases for prediction (validation) should be as close as possible. This is understandable since the construction procurement process is dynamic, and changes constantly with time. Since the collection of Group A and B data was conducted simultaneously it is unlikely to be the case in the developed Z_1 and Z_2 models. However, caution must be taken if the models are used for classifying contractor performance in the 'future'. Examples of the impact of lead time on prediction power can be found in the works of Altman (1968;1993), Deakin (1972) and Blum (1974).

9.6 THE Z_2 MODEL

The classification results of the Z_2 model infer that the contractor evaluation criteria i.e. PSC and levels of importance assigned (LIA) have had significant impact in predicting contractors' performance. It was found that 90% of the cases were correctly classified in the Z_2 model. The external validation results further confirm that the computed models are reasonably good in the classification of new, previously unobserved cases.

The developed Z_2 model consists of five constituent variables (in descending order of contribution of each factor to the function):

i. PSC4-Suitability of the equipment

ii. PSC13- Past performance on similar projects (Cost)

iii. PSC28-Contractor relationship with local authority

iv. PSC15-Contractor reputation and image

v. PSC12-Past performance on similar projects (Time)

The implementation of suitable equipment and plant (for proposed project) is of vital importance in construction activities, particularly, in civil engineering works. Harris and McCaffer (1991) found that extensive (and effective) use of essential plant and equipment has a significant impact on construction time performance. The importance of this criterion was also discussed in Holt *et al.*'s (1994c;1995) investigations.

The past performances of contractors in *cost* and *time* (on similar projects) were found to have significant importance in the discriminant function. These discriminant factors contributed approximately 39% of the total discriminant power of the entire classification results when combined. By undertaking a review of contractors' past performance in terms of cost and time, clients may be able to obtain a 'first hand' feel of contractor performance in their proposed projects and also be able to make a comparison of these performance measures with other contractors. The recently established key performance indicators could provide a useful reference source in this regard (DETR, 2000).

The contractors' relationship with the local authority is a broad indicator of client relationship on public projects. Also it may be linked to familiarity with the local geographical area, and working relationship with local suppliers / labour. This criterion has rarely been extensively discussed in previous studies (e.g. Merna and

Smith, 1990; and Holt *et al.*, 1994c). Obviously, a good relationship with the local authority (i.e. the client on public projects) could well be a significant factor, possibly linked to past performance.

The reputation and image of the contractor may be perceived as being important during the contractor prequalification stage. For instance, for identifying contractors who have undertaken similar 'prestigious' projects and have good performance records. Similarly, this criterion has links with a contractor's past performance. Clients may prefer to work with these contractors because of the perceived longer-term stability and higher profile attached to them. Hence, this could be equally important as other PSC during tender evaluation.

To summarise, the MDA technique has been found robust for classification purposes, and its potential usage for prediction during tender evaluation is also encouraging. The developed model accurately predicts the likelihood of *good* or *poor* contractor performance. One of the advantages for using discriminant analysis is the potential to provide an early warning of inferior contractor performance. If trends of contractor performance can be traced prior to final selection, this allows extra 'precautions' for clients when choosing the appropriate contractor. In addition, the proposed model may apply beyond the purely traditional procurement routes and offers a much more systematic approach to the tender evaluation process.

9.7 FUTURE DEVELOPMENT OF THE MDA MODEL

The discriminant models were developed based upon the relationship of clients' *evaluation preferences* and the consequence of *contractor performance*. By modelling these relationships and coding them into a computer programme, it may be possible to produce a web-based (on-line questionnaire) application. Ideally, this would greatly rationalise the present day quantitative approach for identifying potential contractor(s) in the tender evaluation process.

Further, for more specific usage, divergent MDA models could be developed based on clients' different evaluation settings, where different emphases can be accommodated to suit the requirements of clients and projects (i.e. clients' evaluation preferences and project characteristics). For example, an MDA model for classifying refurbishment project contractors. By this, the derived model would be more specific to the users' requirements by inputting historical data (cases drawn from this domain) with more specific evaluation settings (e.g. type of refurbishment and PSC, size of project, geographical location) to derive the required model. The developed model will then identify the most discriminating factors for predicting contractor's likely performance, which in turn best fits the users' classification circumstances.

9.8 SUMMARY

Results from the independent sample tests show that the derived Z_2 model is reasonably accurate in contractor performance classification. This indicates that contractor classification can be modelled based on clients' tender evaluation preferences i.e. PSC and LIA during tender evaluation. Therefore, it is believed that there is an underlying intrinsic link between the client's evaluation aspirations and the contractors' performance as demonstrated by types of PSC used and LIA during tender evaluation. Both criteria have a significant impact on contractor performance.

The following chapter concludes the research findings and gives recommendations for future research.

CHAPTER 10

CONCLUSIONS AND RECOMMENDATIONS FROM THIS STUDY

10.0 CONCLUSIONS

The UK construction industry has embarked on a vision to meet the challenges of the new millennium. The emphasis on innovative procurement routes, integration of key players in the construction process, standardisation, supply chain management continuous improvement and the remarkable growth of interest in re-engineering business processes in construction have become prominent aspects of the UK construction industry agenda (Latham, 1994; Egan 1998). Recently and as a result of this, the industry has witnessed significant change in construction management process and policies (CIOB, 2000).

Notwithstanding the above, contract award practices have yet to fully benefit from such recommendations (Wong *et al.*, 2000b). Issues regarding: unstructured / non-standardised contractor selection practice and evaluation approaches; lowest-price selection preferences; and open competitive tendering, continue to gain attention from commentators and practitioners from both industry and academia (Jennings and Holt, 1998; CIRIA, 1998; Wong *et al.*, 2000a;2001a). The above changes are of vital importance for improving construction industry performance, particularly, in tender award practices.

10.1 RESEARCH SUMMARY

The research encompassed three main components. The ***first part*** consisted of a literature review and initial survey of UK construction clients, with particular reference to their preferred selection practices. The literature review focused on *contractor prequalification criteria* (PC) and *tender evaluation criteria* (i.e. project-specific criteria, PSC). The initial survey investigated views of, and looked into the background to, present-day prequalification practices. In particular, contrasting views regarding the use of 'in-house' and 'standard' prequalification practices were examined in detail. Both exercises enabled full understanding of client preferences regarding present contractor selection processes and served as a basis for designing and initiating a further two industry-wide empirical surveys of *actual* selection practices (and selection criteria), in a more detailed and structured manner.

The ***second part*** was the execution of a second (industry-wide) empirical survey of public clients, clients' representatives and contractors. Views regarding *levels of importance assigned* (LIA) to contractor selection criteria (i.e. PC and PSC) for given selection settings were observed. Quantitative analysis of these data determined conflicting views (i.e. lowest price or multi-criteria selection?) regarding LIA to criteria for given types of: (i) projects; and (ii) clients. The observed PSC were then carefully selected for use in the final part of the investigation.

The ***third part*** involved the use of the MDA technique to classify contractor performance into 'good' and 'poor' groups, based upon the LIA for each respective PSC from the surveyed practitioners via case studies. The derived models were tested on independent samples. Quantitative analyses of this case study data subsequently developed Z_1 and Z_2 models for classifying contractor performance in building and civil engineering works below £50 million. The former was used to demonstrate the effectiveness of MDA techniques based on three discriminant factors whilst the latter

(Z_2 model) was the **main** classification model based on thirty-one discriminant factors.

10.2 LITERATURE REVIEW

The literature review provided an overview of the UK construction industry, exploring (and helping better understand) the issues surrounding contractor selection practices. This included criticisms from both construction practitioners and commentators, regarding clients' attitudes (i.e. slow in adoption of new management processes, particularly, in the issues of contractor selection and the high incidence of project time and cost overruns). The review also identified intrinsic links between the appointment of a competent (main) contractor and their performance i.e. in terms of meeting clients' time, cost, and quality aspirations.

10.3 INITIAL SURVEY

The initial survey addressed current UK prequalification practices, particularly with respect to perceived merits and demerits. Data collection involved interviews with construction practitioners and follow-up questionnaire surveys among a range of experienced practitioners. The results showed a divergence of opinion pertaining to the use of contractor prequalification practices, such as:

i. use of contractor prequalification lists;

ii. which prequalification criteria to apply; and

iii. prequalification methodologies.

In summary, much has evolved from this survey. The reasons for non-use of standard prequalification list and standard practice have been identified. This provides useful information for reviewing current prequalification practices and for developing standardised prequalification practices. The failings of standardised prequalification practices may be expressed as:

i. lack of flexibility;
ii. lack of tolerance to clients' specific requirements, such as consideration of clients' preferences, geographical / locality concerns, project-specific requirements; and
iii. long term confidence attributed to 'self-developed' database / 'in-house' contractor lists.

10.4 THE SECOND INDUSTRY-WIDE SURVEY

This particular survey investigated a more comprehensive set of PC and PSC and performed an in-depth study of their extent of usage and LIA. This investigation was conducted through an industry-wide empirical survey of construction practitioners (public clients / clients' representatives and contractors' views). The findings identified some significant differences of LIA among the respondents for certain PC / PSC and for project types, as reported by the data analysis results.

Views from contractors indicated that in order to be qualified and maximise their potential to secure contracts, they must equip themselves to convey their potential ability to meet clients' expectations i.e. to achieve good performance in PC / PSC and meeting the demands of rigorous selection exercises. Thus, these findings best mirror client objectives and project needs.

The 'lowest-price wins' selection preference was also discussed with comparison to the multi-criteria selection (MCS) approach. The survey evidence shows that the industry is moving towards a more MCS approach.

10.5 CONTRACTOR CLASSIFICATION MODELS

It is believed that contractor performance is multidimensional and can be measured and determined via a function, or a number of attributes. Therefore, in this research, contractor performance classification models (i.e. Z_1 and Z_2 models) were developed based on 48 case studies (and were tested by 20 independent cases): 31 contractor evaluation criteria (i.e. PSC) observed from detailed literature review and the second industry-wide survey were used in the Z_2 Model. These PSC are conceived to be the intrinsic features of contractor performance (i.e. *good* or *poor*). The results of the tests are shown in Table 10.1.

Table 10. 1: Percentage of Cases Correctly Classified in Z_1 and Z_2 Models

	Classification Models	
	$^1Z_1$	$^2Z_2$
% of correctly classified cases in 48 cases	88	90
% of correctly classified in test samples (20 cases)	70	70

[1] *Exploratory model - for classifying contractors' time, cost and quality performances.*
[2] *The main model - for classifying contractors' performance in 31 PSC (refer, Table 9.2).*

The effectiveness of the classification models was enhanced by application of additional independent test samples. The test results revealed that the models were able to discriminate between *good* and *poor* contractors with a good degree of accuracy.

10.6 SALIENT FINDINGS

The following salient findings can be drawn from this research:

i. The UK construction industry is unique in its methods of working. Fragmentation, increased complexity, the use of a wide variety of procurement routes and fierce competition inhabit the use of standardised contractor selection methods (Wong *et al.*, 2001f).

ii. The use of a *standard* and *single national register* of contractors for pre-qualification is yet to be widely accepted by the UK construction industry (Wong *et al.*, 2000b).

iii. The 'lowest-price wins' principle is not the ultimate option; the choice of final selection is now certainly being tempered with 'value' (rather than lowest capital cost) (Wong *et al.*, 2000a;2001a).

iv. A set of criteria (i.e. PC and PSC) have been defined in light of given types of projects, and different types of client (Wong *et al.*, 2000c).

v. Significant differences have been pinpointed in the LIA emphasised among public clients and clients' representatives in respect of PC and PSC, for both building and civil engineering work sectors (Wong *et al.*, 1999;2001b).

vi. A quantitative technique for classifying contractor performance (i.e. MDA models) has been developed. The models were considered accurate in predicting contractor performance based on clients' selection preferences (Wong *et al.*, 2001c;2001d;2001e).

This research has produced ten academic papers (three are presently under review) in refereed journals and international conferences (refer to references). Findings pertaining to contractor evaluation criteria and contractor classification model were also presented to The Royal Institution of Chartered Surveyors and accepted for funding under the Education Trust Research Programme.

Dissemination of the research has also generated tremendous interest from construction practitioners; both public clients and clients' representatives. This confirms that the potential of this work has been recognised by others (Appendix N).

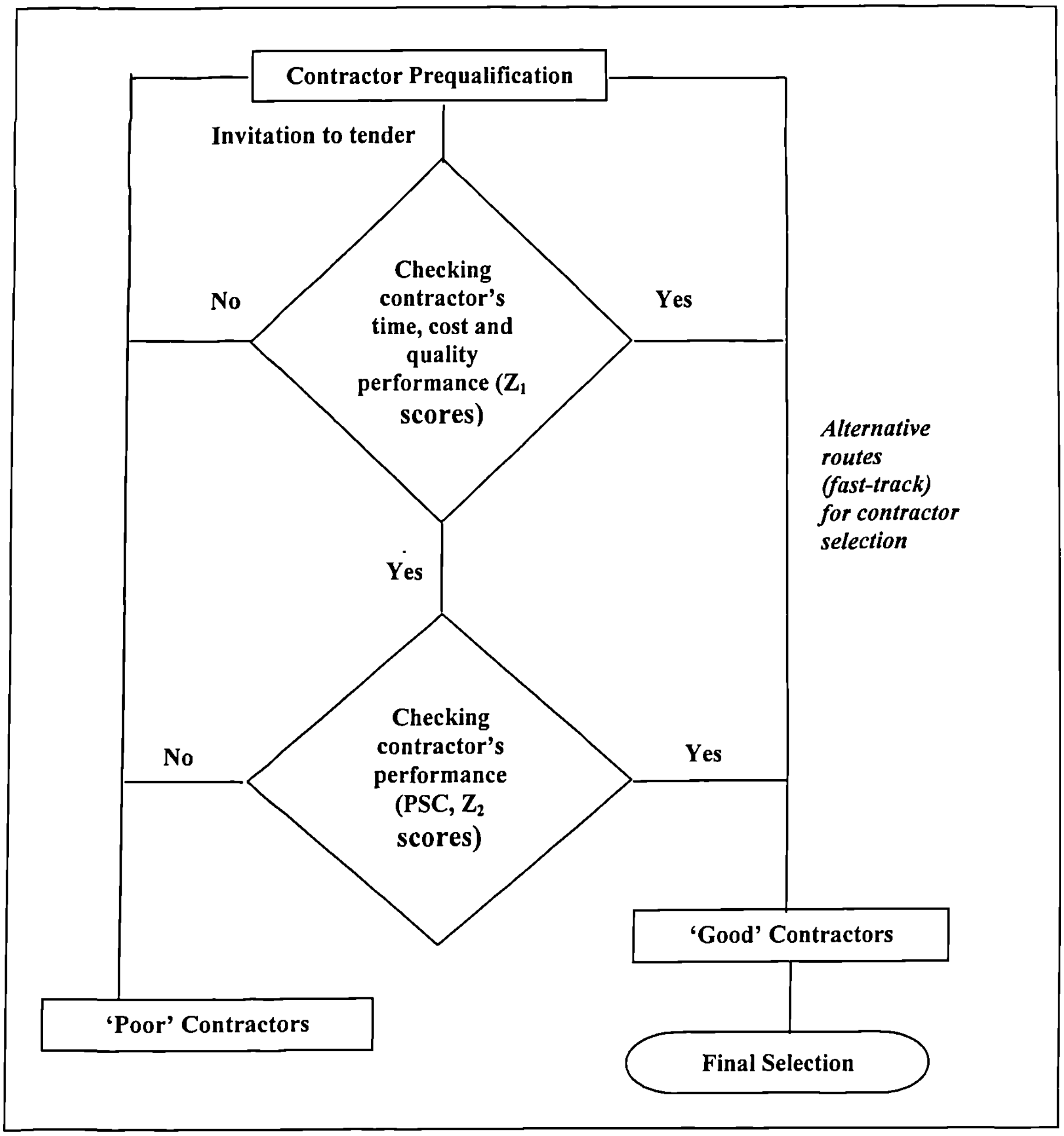
10.7 FUTURE WORK

A systematic contractor classification procedure was proposed as a future development of this research study. Figure 10.1 shows an outline of this systematic contractor selection approach for use at contractor prequalification and tender evaluation stages. The proposed procedure should only be used for complementing (or as part of) an overall contractor selection process. The implementation of contractor classification procedure would be:

Step 1: Checking the contractors' prequalification.

Step 2: Invitation-to-tender of the qualified contractors.

Figure 10 1: Proposed Contractor Classification Procedure: A Conceptual Study



Step 3: Checking contractor performance (time, cost and quality performance according to Z_1 scores) and classifying contractors into 'good' and 'poor groups.

Step 4: Checking contractor performance (project-specific criteria, according to Z_2 scores) and classifying contractors into 'good' and 'poor groups.

In the proposed procedure, the classification procedure should be interpreted with caution since the models require further modification and testing on a more 'project-specific' selection setting.

10.8 RECOMMENDATIONS

Contractor selection exercises need to be more standardised, particularly, in the context of prequalification before tendering. This has been initiated by the research of Holt *et al.* (1993) and was recommended by Latham (1994). The Construction Industry Board (CIB, 1997a;1997b) and the Department of Environment, Transport and the Regions (DETR) have attempted to address this requirement i.e. National Qualification System (NQS), a standard and national contractor register list. However, the response to and adoption of this standard practice (from construction clients) is still considerably slow. The slow adoption has resulted in continuing fragmented prequalification practices and impedance of disseminating the use of single and standardised contractor prequalification lists (Wong *et al.*, 2000c).

The impetus to reinforce standardisation is needed, perhaps this could be achieved by taking account of construction clients' selection aspirations / preferences, and more project-specific considerations into the standardisation initiative and, systemically assessing clients' prioritised requirements (needs) whilst directing resources more efficiently. Overall, the key to maximising benefits is to promote the use of structured and standardised selection practices; both in public clients and clients' representatives, and for public and private sectors of works.

From another aspect, standardisation is necessary to improve construction productivity and its competitive edge. Electronic-commerce (i.e. E-commerce) has rapidly become the focus of attention for business in every field of today's industry and commerce. Standardisation in contractor selection could also benefit from the increased use of E-commerce. Standardisation means efficiency in transferring data between buyers and suppliers (i.e. client and main contractor). It is expected that, such digital marketplaces will benefit both clients and contractors; the former able to access a wider field of potential and competent contractors, hence more competitive prices and value for money; the latter means more tender opportunities.

More importantly, when (construction) E-commerce trading has achieved a certain critical mass transaction level, contractor practitioners could benefit from substantial cost cutting in prequalification and tendering expenditure (e.g. invitation, writing specifications and compilation of contractor lists on-line).

The proposed classification models i.e. Z_1 and Z_2 models in this research should be considered as preliminary and suitable for further modification, for use in a more project-specific or 'client-types' environments. In future research, such a classification model could be more (e.g. project) specific and effectively used in different tender evaluation settings, if the collected (raw) data has been based on typical project (or client characteristics) for the modelling process. In this instance, construction clients would be able to develop individual classification models to meet their specific requirements, based on the input from each typical group of historical cases for given types of project requirements.

In this research, the contractor classification models developed were based mainly on *quantitative attributes* and demonstrate the effectiveness of MDA techniques for classification purposes. Nevertheless, contractor's qualitative data (e.g. productivity performance and expressions of interest for the proposed project) may be considered in future works. To achieve this, the use of non-conventional modelling techniques capable of evaluating complex combinations of quantitative and qualitative data will be essential and recommended for future studies. For instance, the use of evidential rationing (e.g. Yang and Singh, 1994; Yang and Sen, 1997; and Sönmez et al., 2001) and artificial neural networks techniques (e.g. Moselhi et al., 1991; Tam et al., 1995; Ripley et al., 1996; and Lam et al., 2000), may be appropriate.

The author believes that research into contractor selection will continue to grow, particularly, through the increased use of information technology alongside more stringent selection scenarios.

10.9 SUMMARY

This research has investigated in detail UK construction contractor selection, including the application of current prequalification and project-specific criteria. Attempt has also been made to ascertain the relationship between these selection criteria (tender evaluation criteria) and how to select a *good* contractor. The developed classification models have achieved this objective. This classification framework provides a quantitative approach in identifying suitable contractor(s) for a project.

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Appendix A1: Questionnaire Survey- Contractor Prequalification

Q1. Company turnover (if you are a private client) / Annual budget (if you are public client).

Q2. What type of the following systems have you used in your organisation to compile a contractor list for invitation to tender during the past three years? You may tick more than one.

	Tick here	*Approximate number and value of works*
(a). National Quality System (NQS). --	( )	....
(b). European Union Works and Services Directives. -------------------------------	( )	....
(c). Other *national contractor lists* or similar standard practices. (please state).	( )	....
(d). Own 'in-house' / ad-hoc list:	( )	....

Q3. During the pre-selection process, do you involve the following steps investigating the contractors? You may tick more than one.

(a). Sending out questionnaire / enquiry letter to contractors. -- ( )
(b). Use of the information obtained from **Q2- (a) to (d)** criteria. --------------------------------------- ( )
(c). Inviting contractors for an interview. --- ( )
(d). Contacting the referees / third parties/surety company *(delete as appropriate). ------------------ ( )
(e). Other (please state).. ( )

Q4. What are the major criteria you are looking at when drawing up a 'prequalification' list?

( ) Managerial
( ) Health & safety
( ) Quality performance
( ) Other (please state)
....

( ) Company size & reputation
( ) Claims / litigation history
( ) Partnering/prior wo.king relationship

( ) Technical Expertise
( ) Financial stability
( ) Past performance

Q5. Please answer the following questions if you have reluctance to use the national contractor list or the quality register of approved contractors list (as mentioned in **Q2-(a) to (d)**) in your prequalification system(s).
I do not use the national *contractor list* because (You may tick more than one):

(a). It does not cover the client's preferences. --- ( )
(b). It does not take into account project-specific requirements. -- ( )
(c). It covered too many numbers of contractors. -- ( )
(d). It required more, more time, and cost and resource implication for prequalification process. ----- ( )
(e). It is not meaningful to the specific area, such as (please state). --------------------------- ( )
....
(g). Other reasons, (please state). .... ( )
.... ( )
.... ( )

Please tick here if you would like to receive a summary of this study. ----------------------------------( )
Please write your details as follow in order to send you the questionnaire and summary of this survey.

Name: .... Depart.: .... Tel. no: ....
Address:..
....
....
....

Appendix B1: Client's Questionnaire

This questionnaire investigates your opinions regarding contractor prequalification and evaluation. All responses will be treated in confidence and used only for academic research. The questionnaire is in three parts:

Component 1: Asks about your company, for data classification purposes.
Component 2: Asks about factors that you consider when prequalifying contractors.
Component 3: Asks about factors that you might consider when tender evaluation for a (specific) project.

Component 1:
Q1. Location of Head Office (Name the town or region):..
Q2. Nature of business:..

Instructions for Q3 - Please indicate the approximate number and total value of projects assigned by your company during the past 3 years. For example, if you have assigned 2 refurbishment projects total value £ I million in the last 3 years then:

	Number	*Work type*	*Total Value*
Building	2	refurbishment	£1 million

Q3. What type of construction works have you assigned during the past 3 years (in your 3 years contractor selection experience)?

	Number	*Total Value*
3.1 Building	....	....
3.2 Civil Engineering	....	....
3.3 Other, please specify	....	....

Component 2:
Instructions for Q4. You are now asked how important you perceive certain *contractor prequalification criteria.* You are also asked for which *class(es) of work* you think these criteria are important. Please do this on the scale of 1 to 5 and indicate the class(es) of work in the right-hand column. The class(es) ***are 'B' for Buildings; 'C' for Civil Engineering; and 'O' for all or 'other' (please state).*** For example, if you perceive that *Current Workload* is *very important* in selecting a contractor for *civil engineering works* then:

	No importance		*Moderate Importance*		*Maximum Importance*	*Aspect (B,C, or O)*
Contractor's current work load	*1*	*2*	*3*	*4*	*5*	*C*

Q4. Prequalification Criteria

	No importance		*Moderate Importance*		*Maximum Importance*	*Aspect (B,C, or O)*
1. Contractor's current work load	*1*	*2*	*3*	*4*	*5*	....
2. Location of home/place for business	*1*	*2*	*3*	*4*	*5*	....
3. Ability to innovate	*1*	*2*	*3*	*4*	*5*	....
4. Insurance Cover	*1*	*2*	*3*	*4*	*5*	....
5. Past performance in terms of time	*1*	*2*	*3*	*4*	*5*	....
6. Past performance in terms of cost	*1*	*2*	*3*	*4*	*5*	....
7. Quality performance record	*1*	*2*	*3*	*4*	*5*	....
8. Experience in particular work type(s)	*1*	*2*	*3*	*4*	*5*	....
9. Contractor maximum capacity	*1*	*2*	*3*	*4*	*5*	....
10. Staff training regime	*1*	*2*	*3*	*4*	*5*	....
11. Home office support	*1*	*2*	*3*	*4*	*5*	....
12. Annual turnover	*1*	*2*	*3*	*4*	*5*	....
13. Risk management system	*1*	*2*	*3*	*4*	*5*	....
14. Financial stability	*1*	*2*	*3*	*4*	*5*	....
15. Health and safety record	*1*	*2*	*3*	*4*	*5*	....
16. Technical ability and expertise	*1*	*2*	*3*	*4*	*5*	....
17. References/third parties	*1*	*2*	*3*	*4*	*5*	....
18. Bonding capacity	*1*	*2*	*3*	*4*	*5*	....
19. Environmental impact awareness	*1*	*2*	*3*	*4*	*5*	....
20. Design ability	*1*	*2*	*3*	*4*	*5*	....
21. Dispute and claim history	*1*	*2*	*3*	*4*	*5*	....

22. Experience: local or international	*1*	*2*	*3*	*4*	*5*	....
23. Resources(manpower/equipment/labour)	*1*	*2*	*3*	*4*	*5*	....
24. Project management skills (planning, monitoring and control procedures)	*1*	*2*	*3*	*4*	*5*	....
25. Interface of contractor with others	*1*	*2*	*3*	*4*	*5*	....
26. Company size and structure	*1*	*2*	*3*	*4*	*5*	....
27. Site management	*1*	*2*	*3*	*4*	*5*	....
28. Quality of key personnel(s)	*1*	*2*	*3*	*4*	*5*	....
29. Reputation/image	*1*	*2*	*3*	*4*	*5*	....
30. Employees & sub-contractor details s	*1*	*2*	*3*	*4*	*5*	....
31. Understanding of contract/legal issues	*1*	*2*	*3*	*4*	*5*	....
32. Number of years in business	*1*	*2*	*3*	*4*	*5*	....
33. Past performance to particular project	*1*	*2*	*3*	*4*	*5*	....
34. Financial exposure (local or international)	*1*	*2*	*3*	*4*	*5*	....
35. Prior business relationship	*1*	*2*	*3*	*4*	*5*	....
36. Contractor negotiation skill	*1*	*2*	*3*	*4*	*5*	....
37. Past performance in client's previous project(s)	*1*	*2*	*3*	*4*	*5*	....
38. Company nationality	*1*	*2*	*3*	*4*	*5*	....
39. Trade union record	*1*	*2*	*3*	*4*	*5*	....
40. Contractor specific experience	*1*	*2*	*3*	*4*	*5*	....
41. Quality assurance and control procedure	*1*	*2*	*3*	*4*	*5*	....
42. Contractor success/failure contract record(s)	*1*	*2*	*3*	*4*	*5*	....
43. Credit rating	*1*	*2*	*3*	*4*	*5*	....
44. Management capability	*1*	*2*	*3*	*4*	*5*	....
45. Contractor capability to carry out the work	*1*	*2*	*3*	*4*	*5*	....

Component 3:

Instructions for Q5. You are now asked how important you perceive selection criteria, that can be used when evaluating tenderers or, that can be used to assess a contractor's potential for a given specific project.

Q5 Tender Evaluation Criteria / Project-Specific Criteria (PSC)

A). Manpower resources for the particular work:

	No importance		*Moderate Importance*		*Maximum Importance*	*Aspect (B,C, or O)*
1. Quality and quantity of manpower available	*1*	*2*	*3*	*4*	*5*	....
2. Quality and quantity of managerial staff	*1*	*2*	*3*	*4*	*5*	....
3. Amount of decision-making authority on site	*1*	*2*	*3*	*4*	*5*	....
4. Amount of key personnel for the project	*1*	*2*	*3*	*4*	*5*	....
Other (please state)...........................	*1*	*2*	*3*	*4*	*5*	....

B). Equipment resources for the particular work:

	No importance		*Moderate Importance*		*Maximum Importance*	*Aspect (B,C, orO)*
5. Type of plants and equipment available	*1*	*2*	*3*	*4*	*5*	....
6. Size of equipment available	*1*	*2*	*3*	*4*	*5*	....
7. Condition and procedures of equipment	*1*	*2*	*3*	*4*	*5*	....
8. Suitability of the equipment	*1*	*2*	*3*	*4*	*5*	....
Other (please state)...........................	*1*	*2*	*3*	*4*	*5*	....

C). Project management capabilities for the particular work:

	No importance		*Moderate Importance*		*Maximum Importance*	*Aspect (B,C, orO)*
9. Number of professional personnel available	*1*	*2*	*3*	*4*	*5*	....
10. Type of control and monitoring procedures	*1*	*2*	*3*	*4*	*5*	....
11. Availability of project management software	*1*	*2*	*3*	*4*	*5*	....
12. Cost control and reporting systems	*1*	*2*	*3*	*4*	*5*	....
13. Ability to deal with unanticipated problems	*1*	*2*	*3*	*4*	*5*	....
Other (please state)...........................	*1*	*2*	*3*	*4*	*5*	....

D). Geographic location of particular project:

	No importance		Moderate Importance		Maximum Importance	Aspect (B,C, orO)
14. Contractor's familiarity with weather conditions	1	2	3	4	5	....
15. Contractor's familiarity with local labour	1	2	3	4	5	....
16. Contractor's familiarity with local suppliers	1	2	3	4	5	....
17. Contractor's familiarity with geographic area	1	2	3	4	5	....
18. Relationship with Local Authority	1	2	3	4	5	....
Other (please state)………………………..	1	2	3	4	5	....

E). Location of home office:

	No importance		Moderate Importance		Maximum Importance	Aspect (B,C, orO)
19. Home office location relative to job site location	1	2	3	4	5	....
20. Communication and transportation method from office to job site	1	2	3	4	5	....
Other (please state)………………………..	1	2	3	4	5	....

F). Capacity of firm during the particular project:

	No importance		Moderate Importance		Maximum Importance	Aspect (B,C, or O)
21. Current workload	1	2	3	4	5	....
22. Maximum resource/financial capacity	1	2	3	4	5	....
23. Finance arrangements	1	2	3	4	5	....
Other (please state)………………………..	1	2	3	4	5	....

G). Project execution to the proposed project:

	No importance		Moderate Importance		Maximum Importance	Aspect (B,C, or O)
24. Training or skill level of craftsmen	1	2	3	4	5	....
25. Productivity improvement procedures and awareness	1	2	3	4	5	....
26. Site organisation, work rules, work policies	1	2	3	4	5	....
27. Engineering co-ordination	1	2	3	4	5	....
Other (please state)………………………..	1	2	3	4	5	....

H). Technical-economic analysis of the particular project:

	No importance		Moderate Importance		Maximum Importance	Aspect (B,C, or O)
28. Comparison of client's estimate with tender price	1	2	3	4	5	....
29.Comparison between proposal and average tender prices	1	2	3	4	5	....
30. Comparison for client's and proposed direct cost	1	2	3	4	5	....
31. Contractor's errors e.g. proposed construction method / procedure	1	2	3	4	5	....
32. Proposal review e.g. unit price/labour cost/ resources schedule	1	2	3	4	5	....
Other(please state)	1	2	3	4	5	....

I). Other project-specific factors/criteria:

	No importance		Moderate Importance		Maximum Importance	Aspect (B,C, or O)
33. Actual quality achieved in similar works	1	2	3	4	5	....
34. Experience with specific type of facility	1	2	3	4	5	....
35. Proposed construction method	1	2	3	4	5	....
36. Ability to complete on time	1	2	3	4	5	....
37. Actual schedule achieved on similar works	1	2	3	4	5	....
Other (please state)………………………..	1	2	3	4	5	....

Q6. If your company consider that:

1. Tender price is the ***sole basis*** (i.e. lowest price tender) for tender evaluation and selection of a contractor please tick here ( ).
2. Certain essential criteria discussed above have been used in prequalification and tender evaluation, but still selection was dominated by the principle of acceptance of the lowest tender price please tick here ( ).
3. The tender price was ***equally*** as important as PC and PSC in Component 2 & 3 please tick here ( ).

Have you a general comment(s) regarding contractor evaluation/selection criteria? Please do so on the rear of this paper. Your co-operation in this matter is most appreciated- please ticks below if you would like to receive a summary of these research conclusions. Tick: ( ).

Thank you for completing this questionnaire. Please return to:

Appendix B2: Contractor's Questionnaire

This questionnaire investigates your opinions regarding contractor prequalification and evaluation. All responses will be treated in confidence and used only for academic research. The questionnaire is in three parts:

Part 1: Asks about your company, for data classification purposes.
Part 2: Asks about attributes you consider when submitting a contract in tender prequalification stage.
Part 3: Asks about attributes that you might feel 'a good chance of winning this project' when tender evaluation.

Part 1:
Q1. Location of Head Office (Name the town or region):...
Q2. Nature of business:...

Instructions for Q3 - Please indicate the approximate number and total value of projects assigned by your company during the past 3 years. For example, if you have assigned 2 refurbishment projects total value £ I million in the last 3 years then:

	Number	*Work type*	*Total Value*
Building	2	refurbishment	£1 million

Q3. What type of construction works have you assigned during the past 3 years?	*Number*	*Total Value*
3.1 Building	....	....
3.2 Civil Engineering	....	....
3.3 Other, please specify	....	....

Component 2:
Instructions for Q4. You are now asked how important you perceive certain *attributes* are in prequalification, when tendering for a project. You are also asked for which *class(es) of work* you think these *attributes* are important. Please do this on the scale of 1 to 5 and indicate the *class(es)* of work in the right-hand column. The *class(es)* ***are 'B' for Buildings; 'C' for Civil Engineering; and 'A' for all or 'other' (please state).*** For example, if you perceive that *Current Workload* is very important during prequalification of *civil engineering works* then:

	No importance		*Moderate Importance*		*Maximum Importance*	*Aspect (B,C, or O)*
Contractor's current work load	*1*	*2*	*3*	*4*	*5*	*C*

Q4. Pre-selection/Prequalification Factors

	No importance		*Moderate Importance*		*Maximum Importance*	*Aspect (B,C, or O)*
1. Contractor's current work load	*1*	*2*	*3*	*4*	*5*	....
2. Location of home/place for business	*1*	*2*	*3*	*4*	*5*	....
3. Ability to innovate	*1*	*2*	*3*	*4*	*5*	....
4. Insurance Cover	*1*	*2*	*3*	*4*	*5*	....
5. Past performance in terms of time	*1*	*2*	*3*	*4*	*5*	....
6. Past performance in terms of cost	*1*	*2*	*3*	*4*	*5*	....
7. Quality performance record	*1*	*2*	*3*	*4*	*5*	....
8. Experience in particular work type(s)	*1*	*2*	*3*	*4*	*5*	....
9. Contractor maximum capacity	*1*	*2*	*3*	*4*	*5*	....
10. Staff training regime	*1*	*2*	*3*	*4*	*5*	....
11. Home office support	*1*	*2*	*3*	*4*	*5*	....
12. Annual turnover	*1*	*2*	*3*	*4*	*5*	....
13. Risk management system	*1*	*2*	*3*	*4*	*5*	....
14. Financial stability	*1*	*2*	*3*	*4*	*5*	....
15. Health and safety record	*1*	*2*	*3*	*4*	*5*	....
16. Technical ability and expertise	*1*	*2*	*3*	*4*	*5*	....
17. References/third parties	*1*	*2*	*3*	*4*	*5*	....
18. Bonding capacity	*1*	*2*	*3*	*4*	*5*	....
19. Environmental impact awareness	*1*	*2*	*3*	*4*	*5*	....
20. Design ability	*1*	*2*	*3*	*4*	*5*	....

21. Dispute and claim history	*1*	*2*	*3*	*4*	*5*	....
22. Experience: local or international	*1*	*2*	*3*	*4*	*5*	....
23. Resources(manpower/equipment/labour)	*1*	*2*	*3*	*4*	*5*	....
24. Project management skills (planning, monitoring and control procedures)	*1*	*2*	*3*	*4*	*5*	....
25. 'Interface of contractor with others	*1*	*2*	*3*	*4*	*5*	....
26. Company size and structure	*1*	*2*	*3*	*4*	*5*	....
27. Site management	*1*	*2*	*3*	*4*	*5*	....
28. Quality of key personnel(s)	*1*	*2*	*3*	*4*	*5*	....
29. Reputation/image	*1*	*2*	*3*	*4*	*5*	....
30. Employees & sub-contractor details s	*1*	*2*	*3*	*4*	*5*	....
31. Understanding of contract/legal issues	*1*	*2*	*3*	*4*	*5*	....
32. Number of years in business	*1*	*2*	*3*	*4*	*5*	....
33. Past performance to particular project	*1*	*2*	*3*	*4*	*5*	....
34. Financial exposure (local or international)	*1*	*2*	*3*	*4*	*5*	....
35. Prior business relationship	*1*	*2*	*3*	*4*	*5*	....
36. Contractor negotiation skill	*1*	*2*	*3*	*4*	*5*	....
37. Past performance in client's previous project(s)	*1*	*2*	*3*	*4*	*5*	....
38. Company nationality	*1*	*2*	*3*	*4*	*5*	....
39. Trade union record	*1*	*2*	*3*	*4*	*5*	....
40. Contractor specific experience	*1*	*2*	*3*	*4*	*5*	....
41. Quality assurance and control procedure	*1*	*2*	*3*	*4*	*5*	....
42. Contractor success/failure contract record(s)	*1*	*2*	*3*	*4*	*5*	....
43. Credit rating	*1*	*2*	*3*	*4*	*5*	....
44. Management capability	*1*	*2*	*3*	*4*	*5*	....
45. Contractor capability to carry out the work	*1*	*2*	*3*	*4*	*5*	....

Component 3:

Instructions for Q5. If you are being evaluated for a specific project, how important do you feel are the following attributes for winning the project(s)? Please indicate level of importance on the scale 1 to 5 and for which particular class(es) of work the attributes is important, in the right-hand column (classes of work the same as Q6).

Q5 Project-Specific Criteria/Factors for Tender Evaluation

A). Manpower resources for the particular work:

	No importance		*Moderate Importance*		*Maximum Importance*	*Aspect (B,C, or O)*
1. Quality and quantity of manpower available	*1*	*2*	*3*	*4*	*5*	....
2. Quality and quantity of managerial staff	*1*	*2*	*3*	*4*	*5*	....
3. Amount of decision-making authority on site	*1*	*2*	*3*	*4*	*5*	....
4. Amount of key personnel for the project	*1*	*2*	*3*	*4*	*5*	....
Other (please state)............................	*1*	*2*	*3*	*4*	*5*	....

B). Equipment resources for the particular work:

	No importance		*Moderate Importance*		*Maximum Importance*	*Aspect (B,C, orO)*
5. Type of plants and equipment available	*1*	*2*	*3*	*4*	*5*	....
6. Size of equipment available	*1*	*2*	*3*	*4*	*5*	....
7. Condition and procedures of equipment	*1*	*2*	*3*	*4*	*5*	....
8. Suitability of the equipment	*1*	*2*	*3*	*4*	*5*	....
Other (please state)............................	*1*	*2*	*3*	*4*	*5*	....

C). Project management capabilities for the particular work:

	No importance		*Moderate Importance*		*Maximum Importance*	*Aspect (B,C, orO)*
9. Number of professional personnel available	*1*	*2*	*3*	*4*	*5*	....
10. Type of control and monitoring procedures	*1*	*2*	*3*	*4*	*5*	....
11. Availability of project management software	*1*	*2*	*3*	*4*	*5*	....
12. Cost control and reporting systems	*1*	*2*	*3*	*4*	*5*	....
13. Ability to deal with unanticipated problems	*1*	*2*	*3*	*4*	*5*	....
Other (please state)............................	*1*	*2*	*3*	*4*	*5*	....

D). Geographic location of particular project:

	No importance		Moderate Importance		Maximum Importance	Aspect (B,C, or O)
14. Contractor's familiarity with weather conditions	1	2	3	4	5	....
15. Contractor's familiarity with local labour	1	2	3	4	5	....
16. Contractor's familiarity with local suppliers	1	2	3	4	5	....
17. Contractor's familiarity with geographic area	1	2	3	4	5	....
18. Relationship with Local Authority	1	2	3	4	5	....
Other (please state)……………………………	1	2	3	4	5	....

E). Location of home office:

	No importance		Moderate Importance		Maximum Importance	Aspect (B,C, or O)
19. Home office location relative to job site location	1	2	3	4	5	....
20. Communication and transportation method from office to job site	1	2	3	4	5	....
Other (please state)……………………………	1	2	3	4	5	....

F). Capacity of firm during the particular project:

	No importance		Moderate Importance		Maximum Importance	Aspect (B,C, or O)
21. Current workload	1	2	3	4	5	....
22. Maximum resource/financial capacity	1	2	3	4	5	....
23. Finance arrangements	1	2	3	4	5	....
Other (please state)……………………………	1	2	3	4	5	....

G). Project execution to the proposed project:

	No importance		Moderate Importance		Maximum Importance	Aspect (B,C, or O)
24. Training or skill level of craftsmen	1	2	3	4	5	....
25. Productivity improvement procedures and awareness	1	2	3	4	5	....
26. Site organisation, work rules, work policies	1	2	3	4	5	....
27. Engineering co-ordination	1	2	3	4	5	....
Other (please state)……………………………	1	2	3	4	5	....

H). Other project-specific factors/criteria:

	No importance		Moderate Importance		Maximum Importance	Aspect (B,C, or O)
28. Actual quality achieved in similar works	1	2	3	4	5	....
29. Experience with specific type of facility	1	2	3	4	5	....
30. Proposed construction method	1	2	3	4	5	....
31. Ability to complete on time	1	2	3	4	5	....
32. Actual schedule achieved on similar works	1	2	3	4	5	....
Other (please state)……………………………	1	2	3	4	5	....

Q6. Based on your past experience, Please tick ***only one*** of the following.

( ) Tender price is the sole basis for tender evaluation and selection of a contractor.

( ) Certain essential criteria discussed above have been used in prequalification and tender evaluation, but still selection was dominated by the principle of acceptance of the lowest tender price.

( ) Tender price was equally as important as those criteria discussed above.

Have you a general comment(s) regarding contractor evaluation/selection criteria? Please do so overleaf. Your co-operation in this matter is most appreciated. Please tick below if you would like to receive a summary of these research conclusions. Tick: ( ).

Thank you for completing this questionnaire. Please return to:

Appendix C1: Parametric Test for Building Works (PC)

		Sum of Squares	*Mean Square*	*F*	*Sig.*
PC1	Between Groups	0.566	0.283	0.287	0.751
	Within Groups	104.297	0.984		
	Total	104.862			
PC2	Between Groups	1.738	0.869	0.750	0.475
	Within Groups	122.812	1.159		
	Total	124.550			
PC3	Between Groups	6.994	3.497	3.258	**0.042**
	Within Groups	113.776	1.073		
	Total	120.771			
PC4	Between Groups	32.587	16.294	13.079	**0.000**
	Within Groups	132.052	1.246		
	Total	164.640			
PC5	Between Groups	0.700	0.350	0.660	0.519
	Within Groups	56.218	0.530		
	Total	56.918			
PC6	Between Groups	0.876	0.438	0.867	0.423
	Within Groups	53.537	0.505		
	Total	54.413			
PC7	Between Groups	2.033	1.016	2.331	0.102
	Within Groups	46.206	0.436		
	Total	48.239			
PC8	Between Groups	0.222	0.111	0.207	0.813
	Within Groups	56.641	0.534		
	Total	56.862			
PC9	Between Groups	1.856	0.928	1.210	0.302
	Within Groups	81.286	0.767		
	Total	83.142			
PC10	Between Groups	6.896	3.448	3.540	**0.032**
	Within Groups	103.241	0.974		
	Total	110.138			
PC11	Between Groups	0.291	0.145	0.129	0.879
	Within Groups	119.599	1.128		
	Total	119.889			
PC12	Between Groups	0.923	0.462	0.419	0.659
	Within Groups	116.820	1.102		
	Total	117.743			
PC13	Between Groups	5.337	2.669	2.462	0.090
	Within Groups	114.911	1.084		
	Total	120.248			
PC14	Between Groups	3.019	1.509	2.453	0.091
	Within Groups	65.220	0.615		
	Total	68.239			
PC15	Between Groups	7.331	3.665	7.092	**0.001**
	Within Groups	54.784	0.517		
	Total	62.114			
PC16	Between Groups	1.708	0.854	1.675	0.192
	Within Groups	54.053	0.510		
	Total	55.761			
PC17	Between Groups	0.794	0.397	0.421	0.658
	Within Groups	99.962	0.943		
	Total	100.756			
PC18	Between Groups	1.426	0.713	0.621	0.540
	Within Groups	121.780	1.149		
	Total	123.206			
PC19	Between Groups	0.946	0.473	0.428	0.653
	Within Groups	117.307	1.107		
	Total	118.253			
PC20	Between Groups	13.141	6.570	5.304	**0.006**
	Within Groups	131.317	1.239		
	Total	144.458			
PC21	Between Groups	11.588	5.794	5.927	**0.004**
	Within Groups	103.622	0.978		
	Total	115.210			
PC22	Between Groups	7.154	3.577	4.016	**0.021**
	Within Groups	94.403	0.891		
	Total	101.557			
PC23	Between Groups	1.665	0.833	1.058	0.351
	Within Groups	83.418	0.787		
	Total	85.083			

PC24	Between Groups	1.808	0.904	1.119	0.330
	Within Groups	85.623	0.808		
	Total	87.431			
PC25	Between Groups	1.784	0.892	0.955	0.388
	Within Groups	98.987	0.934		
	Total	100.771			
PC26	Between Groups	0.851	0.425	0.452	0.638
	Within Groups	99.779	0.941		
	Total	100.630			
PC27	Between Groups	0.911	0.456	0.615	0.542
	Within Groups	78.498	0.741		
	Total	79.409			
PC28	Between Groups	4.147	2.074	3.076	**0.050**
	Within Groups	71.462	0.674		
	Total	75.610			
PC29	Between Groups	12.559	6.279	7.586	**0.001**
	Within Groups	87.741	0.828		
	Total	100.300			
PC30	Between Groups	1.081	0.541	0.510	0.602
	Within Groups	112.437	1.061		
	Total	113.519			
PC31	Between Groups	0.028	0.014	0.013	0.987
	Within Groups	114.796	1.083		
	Total	114.824			
PC32	Between Groups	1.812	0.906	0.920	0.402
	Within Groups	104.454	0.985		
	Total	106.266			
PC33	Between Groups	5.042	2.521	4.513	**0.013**
	Within Groups	59.215	0.559		
	Total	64.257			
PC34	Between Groups	5.942	2.971	3.024	0.053
	Within Groups	104.152	0.983		
	Total	110.094			
PC35	Between Groups	21.697	10.848	12.849	**0.000**
	Within Groups	89.496	0.844		
	Total	111.193			
PC36	Between Groups	12.847	6.424	8.084	**0.001**
	Within Groups	84.231	0.795		
	Total	97.078			
PC37	Between Groups	11.933	5.966	7.378	**0.001**
	Within Groups	85.719	0.809		
	Total	97.651			
PC38	Between Groups	6.870	3.435	4.141	**0.019**
	Within Groups	87.937	0.830		
	Total	94.807			
PC39	Between Groups	5.487	2.743	2.503	0.087
	Within Groups	116.162	1.096		
	Total	121.649			
PC40	Between Groups	6.886	3.443	3.590	**0.031**
	Within Groups	101.675	0.959		
	Total	108.561			
PC41	Between Groups	0.125	0.063	0.052	0.950
	Within Groups	128.199	1.209		
	Total	128.324			
PC42	Between Groups	3.864	1.932	1.824	0.166
	Within Groups	112.255	1.059		
	Total	116.119			
PC43	Between Groups	2.726	1.363	1.267	0.286
	Within Groups	114.016	1.076		
	Total	116.742			
PC44	Between Groups	1.634	0.817	1.384	0.255
	Within Groups	62.561	0.590		
	Total	64.194			
PC45	Between Groups	0.354	0.177	0.612	0.544
	Within Groups	30.646	0.289		
	Total	31.000			

Note: PC bolded are significant at 0.05 level.

Appendix C2: Parametric Test for Civil Engineering Works (PC)

	Civil Engineering	Sum of Squares	Mean Square	F	Sig.
PC1	Between Groups	1.891	0.945	1.033	0.364
	Within Groups	42.109	0.915		
	Total	44.000			
PC2	Between Groups	0.947	0.474	0.357	0.701
	Within Groups	60.971	1.325		
	Total	61.918			
PC3	Between Groups	11.834	5.917	5.226	**0.009**
	Within Groups	52.084	1.132		
	Total	63.918			
PC4	Between Groups	13.276	6.638	4.793	***0.013***
	Within Groups	63.703	1.385		
	Total	76.980			
PC5	Between Groups	0.023	0.012	0.025	0.975
	Within Groups	21.609	0.470		
	Total	21.633			
PC6	Between Groups	0.070	0.035	0.075	0.928
	Within Groups	21.563	0.469		
	Total	21.633			
PC7	Between Groups	0.166	0.083	0.214	0.808
	Within Groups	17.834	0.388		
	Total	18.000			
PC8	Between Groups	0.375	0.188	0.437	0.649
	Within Groups	19.747	0.429		
	Total	20.122			
PC9	Between Groups	0.295	0.147	0.257	0.775
	Within Groups	26.387	0.574		
	Total	26.682			
PC10	Between Groups	0.036	0.018	0.020	0.980
	Within Groups	40.454	0.879		
	Total	40.490			
PC11	Between Groups	1.350	0.675	0.729	0.488
	Within Groups	42.570	0.925		
	Total	43.920			
PC12	Between Groups	0.517	0.259	0.282	0.756
	Within Groups	42.258	0.919		
	Total	42.776			
PC13	Between Groups	2.585	1.292	1.076	0.349
	Within Groups	55.252	1.201		
	Total	57.837			
PC14	Between Groups	2.992	1.496	5.290	**0.009**
	Within Groups	13.008	0.283		
	Total	16.000			
PC15	Between Groups	1.878	0.939	2.405	0.101
	Within Groups	17.959	0.390		
	Total	19.837			
PC16	Between Groups	1.607	0.803	2.567	0.088
	Within Groups	14.393	0.313		
	Total	16.000			
PC17	Between Groups	0.794	0.397	0.486	0.618
	Within Groups	37.545	0.816		
	Total	38.338			
PC18	Between Groups	1.278	0.639	0.576	0.566
	Within Groups	50.967	1.108		
	Total	52.245			
PC19	Between Groups	0.822	0.411	0.466	0.630
	Within Groups	40.566	0.882		
	Total	41.388			
PC20	Between Groups	11.767	5.884	4.708	**0.014**
	Within Groups	57.485	1.250		
	Total	69.253			
PC21	Between Groups	17.448	8.724	11.615	**0.000**
	Within Groups	34.552	0.751		
	Total	52.000			
PC22	Between Groups	3.825	1.913	3.035	0.058
	Within Groups	28.991	0.630		
	Total	32.816			
PC23	Between Groups	1.410	0.705	0.888	0.418
	Within Groups	36.508	0.794		
	Total	37.918			

PC24	Between Groups	1.654	0.827	1.145	0.327
	Within Groups	33.203	0.722		
	Total	34.857			
PC25	Between Groups	2.729	1.365	1.516	0.230
	Within Groups	41.393	0.900		
	Total	44.122	2.265		
PC26	Between Groups	0.668	0.334	0.439	0.647
	Within Groups	34.965	0.760		
	Total	35.633			
PC27	Between Groups	0.334	0.167	0.208	0.813
	Within Groups	36.909	0.802		
	Total	37.242			
PC28	Between Groups	1.291	0.646	1.619	0.209
	Within Groups	18.342	0.399		
	Total	19.633			
PC29	Between Groups	3.292	1.646	2.331	0.109
	Within Groups	32.473	0.706		
	Total	35.765			
PC30	Between Groups	2.209	1.105	1.111	0.338
	Within Groups	45.750	0.995		
	Total	47.959			
PC31	Between Groups	1.874	0.937	0.936	0.399
	Within Groups	46.043	1.001		
	Total	47.917			
PC32	Between Groups	4.731	2.365	2.585	0.086
	Within Groups	42.085	0.915		
	Total	46.816			
PC33	Between Groups	3.184	1.592	3.892	**0.027**
	Within Groups	18.816	0.409		
	Total	22.000			
PC34	Between Groups	2.056	1.028	1.307	0.281
	Within Groups	36.177	0.786		
	Total	38.233			
PC35	Between Groups	3.274	1.637	1.495	0.235
	Within Groups	50.359	1.095		
	Total	53.633			
PC36	Between Groups	3.288	1.644	2.726	0.076
	Within Groups	27.744	0.603		
	Total	31.032			
PC37	Between Groups	3.543	1.771	2.511	0.092
	Within Groups	32.457	0.706		
	Total	36.000			
PC38	Between Groups	5.834	2.917	3.396	**0.042**
	Within Groups	39.513	0.859		
	Total	45.347			
PC39	Between Groups	5.389	2.694	3.057	0.057
	Within Groups	40.548	0.881		
	Total	45.936			
PC40	Between Groups	3.102	1.551	2.252	0.117
	Within Groups	31.686	0.689		
	Total	34.788			
PC41	Between Groups	6.771	3.386	3.611	**0.035**
	Within Groups	43.124	0.937		
	Total	49.896			
PC42	Between Groups	1.569	0.784	0.689	0.507
	Within Groups	52.376	1.139		
	Total	53.945			
PC43	Between Groups	3.470	1.735	2.316	0.110
	Within Groups	34.459	0.749		
	Total	37.929			
PC44	Between Groups	0.715	0.357	0.810	0.451
	Within Groups	20.297	0.441		
	Total	21.012			
PC45	Between Groups	0.285	0.142	0.599	0.554
	Within Groups	10.941	0.238		
	Total	11.226			

Note: PC bolded are significant at 0.05 level.

Appendix D: Non-Parametric Tests for Building & Civil Engineering Works (PC)

	Building			Civil E		
	Chi-Square	*df*	*Sig.*	*Chi-Square*	*df*	*Sig.*
PC1	0.507	2	0.776	1.624	2	0.444
PC2	0.875	2	0.646	0.984	2	0.612
PC3	6.849	2	**0.033**	8.789	2	**0.012**
PC4	24.628	2	**0.000**	8.755	2	**0.013**
PC5	1.540	2	0.463	0.411	2	0.814
PC6	1.537	2	0.464	0.288	2	0.866
PC7	6.907	2	**0.032**	0.416	2	0.812
PC8	0.027	2	0.987	1.125	2	0.570
PC9	3.690	2	0.158	0.532	2	0.766
PC10	6.760	2	**0.034**	0.197	2	0.906
PC11	0.364	2	0.834	1.176	2	0.555
PC12	0.781	2	0.677	0.319	2	0.852
PC13	5.251	2	0.072	2.184	2	0.336
PC14	6.855	2	**0.032**	7.853	2	**0.020**
PC15	11.024	2	**0.004**	3.491	2	0.175
PC16	4.281	2	0.118	5.216	2	0.074
PC17	0.465	2	0.793	0.319	2	0.852
PC18	1.645	2	0.439	1.112	2	0.574
PC19	0.950	2	0.622	1.284	2	0.526
PC20	10.780	2	**0.005**	7.818	2	**0.020**
PC21	11.252	2	**0.004**	15.425	2	**0.000**
PC22	5.911	2	0.052	5.937	2	0.051
PC23	2.651	2	0.266	1.351	2	0.509
PC24	1.243	2	0.537	1.575	2	0.455
PC25	1.851	2	0.396	3.369	2	0.186
PC26	0.818	2	0.664	0.601	2	0.740
PC27	1.604	2	0.448	0.957	2	0.620
PC28	5.968	2	0.051	3.196	2	0.202
PC29	12.004	2	**0.002**	4.278	2	0.118
PC30	1.187	2	0.552	1.846	2	0.397
PC31	0.067	2	0.967	1.855	2	0.396
PC32	1.823	2	0.402	6.015	2	**0.049**
PC33	8.776	2	**0.012**	6.947	2	**0.031**
PC34	5.546	2	0.062	2.294	2	0.318
PC35	20.124	2	**0.000**	2.093	2	0.351
PC36	11.796	2	**0.003**	4.609	2	0.100
PC37	13.588	2	**0.001**	4.720	2	0.094
PC38	10.381	2	**0.006**	7.510	2	**0.023**
PC39	4.944	2	0.084	5.038	2	0.081
PC40	8.205	2	**0.017**	4.627	2	0.099
PC41	0.089	2	0.956	6.643	2	**0.036**
PC42	7.355	2	**0.025**	3.320	2	0.190
PC43	2.968	2	0.227	3.698	2	0.157
PC44	2.096	2	0.351	1.387	2	0.500
PC45	1.012	2	0.603	0.562	2	0.755

Note: PC bolded are significant at 0.05, 0.005 and 0.0005 levels.

Appendix E1: 95% Confidence Intervals for Building Works (PC)

		Mean	Std. Deviation	Std. Error	95% Confidence Interval for LIA Mean Lower Bound	Upper Bound
PC1	Public	3.365	0.908	0.126	3.113	3.618
	Client's R	3.500	1.108	0.190	3.113	3.887
	Contractor	3.522	0.994	0.207	3.092	3.952
PC2	Public	2.808	1.189	0.165	2.477	3.139
	Client's R	3.088	1.026	0.176	2.730	3.446
	Contractor	3.000	0.853	0.178	2.631	3.369
PC3	Public	2.692	1.039	0.144	2.403	2.982
	Client's R	3.147	1.077	0.185	2.771	3.523
	Contractor	3.261	0.964	0.201	2.844	3.678
PC4	Public	4.500	0.960	0.133	4.233	4.767
	Client's R	3.888	1.196	0.205	3.471	4.305
	Contractor	3.087	1.311	0.273	2.520	3.654
PC5	Public	4.373	0.766	0.106	4.160	4.586
	Client's R	4.441	0.660	0.113	4.211	4.672
	Contractor	4.217	0.736	0.153	3.899	4.536
PC6	Public	4.375	0.816	0.113	4.148	4.602
	Client's R	4.559	0.561	0.096	4.363	4.755
	Contractor	4.348	0.647	0.135	4.068	4.628
PC7	Public	4.404	0.774	0.107	4.188	4.619
	Client's R	4.559	0.561	0.096	4.363	4.755
	Contractor	4.174	0.491	0.102	3.962	4.386
PC8	Public	4.404	0.799	0.111	4.182	4.626
	Client's R	4.441	0.746	0.128	4.181	4.702
	Contractor	4.522	0.511	0.106	4.301	4.743
PC9	Public	3.808	1.030	0.143	3.521	4.094
	Client's R	3.780	0.728	0.125	3.526	4.034
	Contractor	3.478	0.665	0.139	3.191	3.766
PC10	Public	3.221	1.152	0.160	2.900	3.542
	Client's R	3.059	0.694	0.119	2.817	3.301
	Contractor	2.565	0.945	0.197	2.157	2.974
PC11	Public	2.924	1.202	0.167	2.589	3.259
	Client's R	2.824	0.936	0.161	2.497	3.150
	Contractor	2.952	0.878	0.183	2.573	3.332
PC12	Public	3.308	1.276	0.177	2.952	3.663
	Client's R	3.147	0.857	0.147	2.848	3.446
	Contractor	3.391	0.656	0.137	3.107	3.675
PC13	Public	3.627	1.120	0.155	3.315	3.938
	Client's R	3.118	0.880	0.151	2.811	3.425
	Contractor	3.452	1.076	0.224	2.987	3.917
PC14	Public	4.462	0.874	0.121	4.218	4.705
	Client's R	4.529	0.615	0.105	4.315	4.744
	Contractor	4.087	0.793	0.165	3.744	4.430
PC15	Public	4.673	0.513	0.071	4.530	4.816
	Client's R	4.212	0.844	0.145	3.917	4.506
	Contractor	4.087	0.900	0.188	3.698	4.476
PC16	Public	4.442	0.725	0.101	4.240	4.644
	Client's R	4.265	0.710	0.122	4.017	4.512
	Contractor	4.130	0.694	0.145	3.830	4.431
PC17	Public	3.503	1.071	0.149	3.205	3.801
	Client's R	3.412	0.957	0.164	3.078	3.746
	Contractor	3.652	0.714	0.149	3.343	3.961
PC18	Public	3.501	1.159	0.161	3.179	3.824
	Client's R	3.242	0.986	0.169	2.898	3.586
	Contractor	3.348	0.982	0.205	2.923	3.772
PC19	Public	3.157	1.036	0.144	2.868	3.445
	Client's R	3.088	0.965	0.166	2.752	3.425
	Contractor	2.913	1.203	0.251	2.393	3.433
PC20	Public	2.492	1.178	0.163	2.164	2.820
	Client's R	3.270	1.109	0.190	2.883	3.657
	Contractor	2.996	0.954	0.199	2.583	3.408
PC21	Public	3.805	1.121	0.155	3.493	4.117
	Client's R	4.029	0.717	0.123	3.778	4.279
	Contractor	3.130	1.014	0.211	2.692	3.569
PC22	Public	3.531	1.126	0.156	3.217	3.844
	Client's R	4.088	0.668	0.115	3.855	4.321
	Contractor	3.957	0.825	0.172	3.600	4.313
PC23	Public	3.846	1.017	0.141	3.563	4.129
	Client's R	4.088	0.793	0.136	3.812	4.365
	Contractor	3.783	0.671	0.140	3.492	4.073

PC24	Public	3.746	1.045	0.145	3.455	4.037
	Client's R	4.029	0.758	0.130	3.765	4.294
	Contractor	3.950	0.706	0.147	3.645	4.255
PC25	Public	3.452	0.976	0.135	3.180	3.724
	Client's R	3.735	0.751	0.129	3.473	3.997
	Contractor	3.478	1.201	0.250	2.959	3.998
PC26	Public	3.314	1.146	0.159	2.995	3.633
	Client's R	3.294	0.871	0.149	2.990	3.598
	Contractor	3.522	0.593	0.124	3.265	3.778
PC27	Public	4.021	0.896	0.124	3.771	4.270
	Client's R	4.211	0.844	0.145	3.916	4.506
	Contractor	4.000	0.798	0.166	3.655	4.345
PC28	Public	3.998	0.929	0.129	3.739	4.257
	Client's R	4.412	0.657	0.113	4.183	4.641
	Contractor	4.348	0.775	0.162	4.013	4.683
PC29	Public	3.080	1.045	0.145	2.789	3.371
	Client's R	3.588	0.743	0.127	3.329	3.848
	Contractor	3.913	0.793	0.165	3.570	4.256
PC30	Public	3.196	1.155	0.160	2.875	3.518
	Client's R	3.324	0.878	0.151	3.017	3.630
	Contractor	3.043	0.928	0.194	2.642	3.445
PC31	Public	3.294	1.209	0.168	2.958	3.631
	Client's R	3.331	0.910	0.156	3.014	3.649
	Contractor	3.304	0.765	0.159	2.974	3.635
PC32	Public	2.784	1.054	0.146	2.491	3.078
	Client's R	3.000	0.888	0.152	2.690	3.310
	Contractor	3.087	0.996	0.208	2.656	3.518
PC33	Public	3.692	0.755	0.105	3.482	3.903
	Client's R	4.118	0.729	0.125	3.863	4.372
	Contractor	4.130	0.757	0.158	3.803	4.458
PC34	Public	3.296	1.143	0.158	2.978	3.614
	Client's R	3.828	0.657	0.113	3.599	4.057
	Contractor	3.589	1.030	0.215	3.144	4.034
PC35	Public	3.019	1.038	0.144	2.730	3.308
	Client's R	3.794	0.880	0.151	3.487	4.101
	Contractor	4.043	0.638	0.133	3.768	4.319
PC36	Public	2.577	0.848	0.118	2.341	2.813
	Client's R	3.058	0.919	0.158	2.737	3.379
	Contractor	3.435	0.945	0.197	3.026	3.843
PC37	Public	3.827	1.061	0.147	3.531	4.122
	Client's R	4.294	0.836	0.143	4.002	4.586
	Contractor	4.652	0.487	0.102	4.442	4.863
PC38	Public	1.481	0.852	0.118	1.244	1.718
	Client's R	2.000	0.953	0.164	1.667	2.333
	Contractor	1.957	0.976	0.204	1.534	2.379
PC39	Public	2.203	1.085	0.150	1.901	2.505
	Client's R	2.412	1.076	0.185	2.036	2.787
	Contractor	1.783	0.902	0.188	1.392	2.173
PC40	Public	3.393	1.049	0.146	3.101	3.685
	Client's R	3.787	0.807	0.138	3.505	4.069
	Contractor	4.000	1.044	0.218	3.548	4.452
PC41	Public	3.628	1.171	0.162	3.302	3.954
	Client's R	3.706	1.088	0.187	3.326	4.085
	Contractor	3.652	0.935	0.195	3.248	4.056
PC42	Public	3.881	1.041	0.144	3.591	4.171
	Client's R	3.939	0.983	0.169	3.596	4.282
	Contractor	4.361	1.068	0.223	3.899	4.823
PC43	Public	3.827	1.133	0.157	3.512	4.142
	Client's R	3.815	0.869	0.149	3.512	4.118
	Contractor	3.435	1.037	0.216	2.986	3.883
PC44	Public	4.020	0.852	0.118	3.783	4.257
	Client's R	4.302	0.627	0.108	4.083	4.521
	Contractor	4.130	0.757	0.158	3.803	4.458
PC45	Public	4.706	0.535	0.074	4.557	4.855
	Client's R	4.804	0.518	0.089	4.624	4.985
	Contractor	4.652	0.573	0.119	4.404	4.900

Appendix E2: 95% Confidence Intervals for Civil Engineering Works (PC)

		Mean	Std. Deviation	Std. Error	95% Confidence Interval for LIA Mean Lower Bound	Upper Bound
PC1	Public	3.391	0.891	0.186	3.006	3.777
	Client's R	3.857	1.027	0.275	3.264	4.450
	Contractor	3.583	0.996	0.288	2.950	4.216
PC2	Public	2.826	1.230	0.257	2.294	3.358
	Client's R	3.000	1.109	0.296	2.359	3.641
	Contractor	3.167	1.030	0.297	2.633	3.285
PC3	Public	2.522	1.039	0.217	2.073	2.971
	Client's R	3.429	1.089	0.291	2.800	4.058
	Contractor	3.583	1.084	0.313	2.895	4.272
PC4	Public	4.522	0.898	0.187	4.133	4.910
	Client's R	3.857	1.231	0.329	3.146	4.568
	Contractor	3.250	1.545	0.446	2.268	4.232
PC5	Public	4.391	0.583	0.122	4.139	4.643
	Client's R	4.357	0.633	0.169	3.991	4.723
	Contractor	4.417	0.900	0.260	3.845	4.989
PC6	Public	4.348	0.647	0.135	4.068	4.628
	Client's R	4.429	0.646	0.173	4.055	4.802
	Contractor	4.417	0.793	0.229	3.913	4.920
PC7	Public	4.478	0.593	0.124	4.222	4.735
	Client's R	4.429	0.646	0.173	4.055	4.802
	Contractor	4.333	0.651	0.188	3.919	4.747
PC8	Public	4.565	0.728	0.152	4.251	4.880
	Client's R	4.429	0.646	0.173	4.055	4.802
	Contractor	4.667	0.492	0.142	4.354	4.980
PC9	Public	3.913	0.793	0.165	3.570	4.256
	Client's R	3.765	0.800	0.214	3.303	4.227
	Contractor	3.750	0.622	0.179	3.355	4.145
PC10	Public	3.130	1.014	0.211	2.692	3.569
	Client's R	3.071	0.730	0.195	2.650	3.493
	Contractor	3.083	0.996	0.288	2.450	3.716
PC11	Public	2.783	1.043	0.217	2.332	3.233
	Client's R	3.143	0.864	0.231	2.644	3.642
	Contractor	3.075	0.902	0.260	2.502	3.648
PC12	Public	3.217	1.085	0.226	2.748	3.687
	Client's R	3.429	0.852	0.228	2.937	3.920
	Contractor	3.417	0.793	0.229	2.913	3.920
PC13	Public	3.609	1.196	0.249	3.091	4.126
	Client's R	3.286	0.994	0.266	2.712	3.860
	Contractor	3.917	0.996	0.288	3.284	4.550
PC14	Public	4.783	0.422	0.088	4.600	4.965
	Client's R	4.571	0.514	0.137	4.275	4.868
	Contractor	4.167	0.718	0.207	3.711	4.623
PC15	Public	4.739	0.449	0.094	4.545	4.933
	Client's R	4.286	0.825	0.221	3.809	4.762
	Contractor	4.667	0.651	0.188	4.253	5.081
PC16	Public	4.696	0.470	0.098	4.492	4.899
	Client's R	4.286	0.611	0.163	3.933	4.639
	Contractor	4.667	0.651	0.188	4.253	5.081
PC17	Public	3.733	0.863	0.180	3.359	4.106
	Client's R	3.500	1.019	0.272	2.912	4.088
	Contractor	3.833	0.835	0.241	3.303	4.364
PC18	Public	3.652	0.935	0.195	3.248	4.056
	Client's R	3.500	1.225	0.327	2.793	4.207
	Contractor	3.250	1.055	0.305	2.580	3.920
PC19	Public	3.261	0.915	0.191	2.865	3.657
	Client's R	3.357	1.008	0.269	2.775	3.939
	Contractor	3.583	0.900	0.260	3.011	4.155
PC20	Public	2.522	1.163	0.242	2.019	3.025
	Client's R	3.679	1.067	0.285	3.062	4.295
	Contractor	3.075	1.085	0.313	2.386	3.764
PC21	Public	4.043	0.878	0.183	3.664	4.423
	Client's R	4.071	0.730	0.195	3.650	4.493
	Contractor	2.667	0.985	0.284	2.041	3.292
PC22	Public	3.652	0.832	0.173	3.293	4.012
	Client's R	4.286	0.611	0.163	3.933	4.639
	Contractor	4.083	0.900	0.260	3.511	4.655
PC23	Public	3.783	1.043	0.217	3.332	4.233
	Client's R	4.071	0.730	0.195	3.650	4.493

	Contractor	4.167	0.718	0.207	3.711	4.623
PC24	Public	3.870	1.014	0.211	3.431	4.308
	Client's R	4.286	0.726	0.194	3.866	4.705
	Contractor	4.154	0.583	0.168	3.784	4.525
PC25	Public	3.304	1.020	0.213	2.863	3.745
	Client's R	3.714	0.914	0.244	3.187	4.242
	Contractor	3.833	0.835	0.241	3.303	4.364
PC26	Public	3.696	0.876	0.183	3.317	4.074
	Client's R	3.429	1.016	0.272	2.842	4.015
	Contractor	3.667	0.651	0.188	3.253	4.081
PC27	Public	4.133	0.919	0.192	3.735	4.530
	Client's R	4.227	0.891	0.238	3.713	4.741
	Contractor	4.000	0.853	0.246	3.458	4.542
PC28	Public	4.217	0.671	0.140	3.927	4.508
	Client's R	4.571	0.646	0.173	4.198	4.945
	Contractor	4.500	0.522	0.151	4.168	4.832
PC29	Public	3.135	0.868	0.181	2.759	3.510
	Client's R	3.643	0.842	0.225	3.157	4.129
	Contractor	3.667	0.778	0.225	3.172	4.161
PC30	Public	3.000	1.243	0.259	2.462	3.538
	Client's R	3.500	0.650	0.174	3.124	3.876
	Contractor	3.250	0.754	0.218	2.771	3.729
PC31	Public	3.087	1.164	0.243	2.583	3.590
	Client's R	3.519	0.932	0.249	2.981	4.057
	Contractor	3.417	0.669	0.193	2.992	3.841
PC32	Public	2.609	1.076	0.224	2.143	3.074
	Client's R	3.214	0.893	0.239	2.699	3.730
	Contractor	3.250	0.754	0.218	2.771	3.729
PC33	Public	3.739	0.689	0.144	3.441	4.037
	Client's R	4.143	0.663	0.177	3.760	4.526
	Contractor	4.333	0.492	0.142	4.020	4.646
PC34	Public	3.452	0.940	0.196	3.045	3.859
	Client's R	3.847	0.769	0.206	3.403	4.291
	Contractor	3.879	0.906	0.262	3.304	4.455
PC35	Public	3.130	1.180	0.246	2.620	3.641
	Client's R	3.500	1.019	0.272	2.912	4.088
	Contractor	3.750	0.754	0.218	3.271	4.229
PC36	Public	2.478	0.730	0.152	2.162	2.794
	Client's R	2.995	0.785	0.210	2.542	3.448
	Contractor	3.000	0.853	0.246	2.458	3.542
PC37	Public	3.913	0.949	0.198	3.503	4.324
	Client's R	4.143	0.864	0.231	3.644	4.642
	Contractor	4.583	0.515	0.149	4.256	4.911
PC38	Public	1.478	0.846	0.176	1.112	1.844
	Client's R	2.286	0.994	0.266	1.712	2.860
	Contractor	1.917	0.996	0.288	1.284	2.550
PC39	Public	2.180	0.833	0.174	1.820	2.541
	Client's R	2.786	1.051	0.281	2.179	3.392
	Contractor	1.917	0.996	0.288	1.284	2.550
PC40	Public	3.628	0.829	0.173	3.269	3.986
	Client's R	3.771	0.890	0.238	3.257	4.285
	Contractor	4.250	0.754	0.218	3.771	4.729
PC41	Public	3.178	0.936	0.195	2.773	3.583
	Client's R	3.929	1.072	0.286	3.310	4.547
	Contractor	3.917	0.900	0.260	3.345	4.489
PC42	Public	3.909	1.041	0.217	3.459	4.359
	Client's R	3.771	0.973	0.260	3.209	4.333
	Contractor	4.250	1.215	0.351	3.478	5.022
PC43	Public	4.304	0.703	0.147	4.000	4.608
	Client's R	3.924	0.828	0.221	3.445	4.402
	Contractor	3.667	1.155	0.333	2.933	4.400
PC44	Public	4.130	0.757	0.158	3.803	4.458
	Client's R	4.311	0.462	0.123	4.045	4.578
	Contractor	4.417	0.669	0.193	3.992	4.841
PC45	Public	4.727	0.538	0.112	4.494	4.960
	Client's R	4.907	0.268	0.072	4.752	5.062
	Contractor	4.811	0.576	0.166	4.445	5.176

Appendix F1: Post Hoc Multi Comparisons in Building Works (PC)

Multiple Comparisons (Bonferroni)

Dependent Variables	**Organisation types**		*Mean Difference*	*Std. Error*	*Sig.*
PC1	Public	Client's R	-0.135	0.219	1.000
		Contractor	-0.156	0.248	1.000
	Client's R	Public	0.135	0.219	1.000
		Contractor	-0.022	0.268	1.000
	Contractor	Public	0.156	0.248	1.000
		Client's R	0.022	0.268	1.000
PC2	Public	Client's R	-0.281	0.237	0.720
		Contractor	-0.192	0.270	1.000
	Client's R	Public	0.281	0.237	0.720
		Contractor	0.088	0.291	1.000
	Contractor	Public	0.192	0.270	1.000
		Client's R	-0.088	0.291	1.000
PC3	Public	Client's R	-0.455	0.228	0.147
		Contractor	-0.569	0.259	0.092
	Client's R	Public	0.455	0.228	0.147
		Contractor	-0.114	0.280	1.000
	Contractor	Public	0.569	0.259	0.092
		Client's R	0.114	0.280	1.000
PC4	Public	Client's R	0.612	0.246	0.043
		Contractor	**1.413***	0.280	**0.000**
	Client's R	Public	-0.612	0.246	0.043
		Contractor	0.801	0.301	0.027
	Contractor	Public	**-1.413***	0.280	**0.000**
		Client's R	-0.801	0.301	0.027
PC5	Public	Client's R	-0.068	0.161	1.000
		Contractor	0.156	0.182	1.000
	Client's R	Public	0.068	0.161	1.000
		Contractor	0.224	0.197	0.773
	Contractor	Public	-0.156	0.182	1.000
		Client's R	-0.224	0.197	0.773
PC6	Public	Client's R	-0.184	0.157	0.731
		Contractor	0.027	0.178	1.000
	Client's R	Public	0.184	0.157	0.731
		Contractor	0.211	0.192	0.822
	Contractor	Public	-0.027	0.178	1.000
		Client's R	-0.211	0.192	0.822
PC7	Public	Client's R	-0.155	0.146	0.869
		Contractor	0.230	0.165	0.502
	Client's R	Public	0.155	0.146	0.869
		Contractor	0.385	0.178	0.099
	Contractor	Public	-0.230	0.165	0.502
		Client's R	-0.385	0.178	0.099
PC8	Public	Client's R	-0.037	0.161	1.000
		Contractor	-0.118	0.183	1.000
	Client's R	Public	0.037	0.161	1.000
		Contractor	-0.081	0.197	1.000
	Contractor	Public	0.118	0.183	1.000
		Client's R	0.081	0.197	1.000
PC9	Public	Client's R	0.028	0.193	1.000
		Contractor	0.329	0.219	0.408
	Client's R	Public	-0.028	0.193	1.000
		Contractor	0.302	0.236	0.614
	Contractor	Public	-0.329	0.219	0.408
		Client's R	-0.302	0.236	0.614
PC10	Public	Client's R	0.162	0.218	1.000
		Contractor	0.656	0.247	0.028
	Client's R	Public	-0.162	0.218	1.000
		Contractor	0.494	0.266	0.200

	Contractor	Public	-0.656	0.247	0.028
		Client's R	-0.494	0.266	0.200
PC11	Public	Client's R	0.100	0.234	1.000
		Contractor	-0.028	0.266	1.000
	Client's R	Public	-0.100	0.234	1.000
		Contractor	-0.129	0.287	1.000
	Contractor	Public	0.028	0.266	1.000
		Client's R	0.129	0.287	1.000
PC12	Public	Client's R	0.161	0.232	1.000
		Contractor	-0.084	0.263	1.000
	Client's R	Public	-0.161	0.232	1.000
		Contractor	-0.244	0.283	1.000
	Contractor	Public	0.084	0.263	1.000
		Client's R	0.244	0.283	1.000
PC13	Public	Client's R	0.509	0.230	0.086
		Contractor	0.174	0.261	1.000
	Client's R	Public	-0.509	0.230	0.086
		Contractor	-0.335	0.281	0.710
	Contractor	Public	-0.174	0.261	1.000
		Client's R	0.335	0.281	0.710
PC14	Public	Client's R	-0.068	0.173	1.000
		Contractor	0.375	0.196	0.178
	Client's R	Public	0.068	0.173	1.000
		Contractor	0.442	0.212	0.117
	Contractor	Public	-0.375	0.196	0.178
		Client's R	-0.442	0.212	0.117
PC15	Public	Client's R	**0.461***	0.159	**0.013**
		Contractor	**0.586***	0.180	**0.005**
	Client's R	Public	**-0.461***	0.159	**0.013**
		Contractor	0.125	0.194	1.000
	Contractor	Public	**-0.586***	0.180	**0.005**
		Client's R	-0.125	0.194	1.000
PC16	Public	Client's R	0.178	0.157	0.786
		Contractor	0.312	0.179	0.252
	Client's R	Public	-0.178	0.157	0.786
		Contractor	0.134	0.193	1.000
	Contractor	Public	-0.312	0.179	0.252
		Client's R	-0.134	0.193	1.000
PC17	Public	Client's R	0.091	0.214	1.000
		Contractor	-0.149	0.243	1.000
	Client's R	Public	-0.091	0.214	1.000
		Contractor	-0.240	0.262	1.000
	Contractor	Public	0.149	0.243	1.000
		Client's R	0.240	0.262	1.000
PC18	Public	Client's R	0.259	0.236	0.827
		Contractor	0.153	0.268	1.000
	Client's R	Public	-0.259	0.236	0.827
		Contractor	-0.106	0.289	1.000
	Contractor	Public	-0.153	0.268	1.000
		Client's R	0.106	0.289	1.000
PC19	Public	Client's R	0.068	0.232	1.000
		Contractor	0.243	0.263	1.000
	Client's R	Public	-0.068	0.232	1.000
		Contractor	0.175	0.284	1.000
	Contractor	Public	-0.243	0.263	1.000
		Client's R	-0.175	0.284	1.000
PC20	Public	Client's R	**-0.778***	0.245	**0.006**
		Contractor	-0.504	0.279	0.221
	Client's R	Public	**0.778***	0.245	**0.006**
		Contractor	0.274	0.300	1.000
	Contractor	Public	0.504	0.279	0.221
		Client's R	-0.274	0.300	1.000
PC21	Public	Client's R	-0.224	0.218	0.920
		Contractor	0.674	0.248	0.023

	Client's R	Public	0.224	0.218	0.920
		Contractor	**0.898***	0.267	**0.003**
	Contractor	Public	-0.674	0.248	0.023
		Client's R	**-0.898***	0.267	**0.003**
PC22	Public	Client's R	-0.557	0.208	0.026
		Contractor	-0.426	0.236	0.223
	Client's R	Public	0.557	0.208	0.026
		Contractor	0.132	0.255	1.000
	Contractor	Public	0.426	0.236	0.223
		Client's R	-0.132	0.255	1.000
PC23	Public	Client's R	-0.242	0.196	0.656
		Contractor	0.064	0.222	1.000
	Client's R	Public	0.242	0.196	0.656
		Contractor	0.306	0.240	0.614
	Contractor	Public	-0.064	0.222	1.000
		Client's R	-0.306	0.240	0.614
PC24	Public	Client's R	-0.284	0.198	0.466
		Contractor	-0.204	0.225	1.000
	Client's R	Public	0.284	0.198	0.466
		Contractor	0.079	0.243	1.000
	Contractor	Public	0.204	0.225	1.000
		Client's R	-0.079	0.243	1.000
PC25	Public	Client's R	-0.283	0.213	0.560
		Contractor	-0.026	0.242	1.000
	Client's R	Public	0.283	0.213	0.560
		Contractor	0.257	0.261	0.980
	Contractor	Public	0.026	0.242	1.000
		Client's R	-0.257	0.261	0.980
PC26	Public	Client's R	0.020	0.214	1.000
		Contractor	-0.208	0.243	1.000
	Client's R	Public	-0.020	0.214	1.000
		Contractor	-0.228	0.262	1.000
	Contractor	Public	0.208	0.243	1.000
		Client's R	0.228	0.262	1.000
PC27	Public	Client's R	-0.190	0.190	0.955
		Contractor	0.021	0.215	1.000
	Client's R	Public	0.190	0.190	0.955
		Contractor	0.211	0.232	1.000
	Contractor	Public	-0.021	0.215	1.000
		Client's R	-0.211	0.232	1.000
PC28	Public	Client's R	-0.414	0.181	0.073
		Contractor	-0.350	0.206	0.276
	Client's R	Public	0.414	0.181	0.073
		Contractor	0.064	0.222	1.000
	Contractor	Public	0.350	0.206	0.276
		Client's R	-0.064	0.222	1.000
PC29	Public	Client's R	-0.508	0.201	0.038
		Contractor	**-0.833***	0.228	**0.001**
	Client's R	Public	0.508	0.201	0.038
		Contractor	-0.325	0.246	0.567
	Contractor	Public	**0.833***	0.228	**0.001**
		Client's R	0.325	0.246	0.567
PC30	Public	Client's R	-0.127	0.227	1.000
		Contractor	0.153	0.258	1.000
	Client's R	Public	0.127	0.227	1.000
		Contractor	0.280	0.278	0.948
	Contractor	Public	-0.153	0.258	1.000
		Client's R	-0.280	0.278	0.948
PC31	Public	Client's R	-0.037	0.230	1.000
		Contractor	-0.010	0.261	1.000
	Client's R	Public	0.037	0.230	1.000
		Contractor	0.027	0.281	1.000
	Contractor	Public	0.010	0.261	1.000
		Client's R	-0.027	0.281	1.000

PC32	Public	Client's R	-0.216	0.219	0.981
		Contractor	-0.303	0.249	0.679
	Client's R	Public	0.216	0.219	0.981
		Contractor	-0.087	0.268	1.000
	Contractor	Public	0.303	0.249	0.679
		Client's R	0.087	0.268	1.000
PC33	Public	Client's R	-0.425	0.165	0.034
		Contractor	-0.438	0.187	0.063
	Client's R	Public	0.425	0.165	0.034
		Contractor	-0.013	0.202	1.000
	Contractor	Public	0.438	0.187	0.063
		Client's R	0.013	0.202	1.000
PC34	Public	Client's R	-0.532	0.219	0.050
		Contractor	-0.293	0.248	0.722
	Client's R	Public	0.532	0.219	0.050
		Contractor	0.239	0.268	1.000
	Contractor	Public	0.293	0.248	0.722
		Client's R	-0.239	0.268	1.000
PC35	Public	Client's R	**-0.775***	0.203	**0.001**
		Contractor	**-1.024***	0.230	**0.000**
	Client's R	Public	**0.775***	0.203	**0.001**
		Contractor	-0.249	0.248	0.951
	Contractor	Public	**1.024***	0.230	**0.000**
		Client's R	0.249	0.248	0.951
PC36	Public	Client's R	-0.481	0.197	0.048
		Contractor	**-0.858***	0.223	**0.001**
	Client's R	Public	0.481	0.197	0.048
		Contractor	-0.377	0.241	0.361
	Contractor	Public	**0.858***	0.223	**0.001**
		Client's R	0.377	0.241	0.361
PC37	Public	Client's R	-0.467	0.198	0.061
		Contractor	**-0.825***	0.225	**0.001**
	Client's R	Public	0.467	0.198	0.061
		Contractor	-0.358	0.243	0.430
	Contractor	Public	**0.825***	0.225	**0.001**
		Client's R	0.358	0.243	0.430
PC38	Public	Client's R	-0.519	0.201	0.033
		Contractor	-0.476	0.228	0.118
	Client's R	Public	0.519	0.201	0.033
		Contractor	0.043	0.246	1.000
	Contractor	Public	0.476	0.228	0.118
		Client's R	-0.043	0.246	1.000
PC39	Public	Client's R	-0.208	0.231	1.000
		Contractor	0.421	0.262	0.335
	Client's R	Public	0.208	0.231	1.000
		Contractor	0.629	0.283	0.084
	Contractor	Public	-0.421	0.262	0.335
		Client's R	-0.629	0.283	0.084
PC40	Public	Client's R	-0.394	0.216	0.213
		Contractor	-0.607	0.245	0.045
	Client's R	Public	0.394	0.216	0.213
		Contractor	-0.213	0.264	1.000
	Contractor	Public	0.607	0.245	0.045
		Client's R	0.213	0.264	1.000
PC41	Public	Client's R	-0.078	0.243	1.000
		Contractor	-0.024	0.275	1.000
	Client's R	Public	0.078	0.243	1.000
		Contractor	0.054	0.297	1.000
	Contractor	Public	0.024	0.275	1.000
		Client's R	-0.054	0.297	1.000
PC42	Public	Client's R	-0.058	0.227	1.000
		Contractor	-0.480	0.258	0.196
	Client's R	Public	0.058	0.227	1.000
		Contractor	-0.422	0.278	0.395

	Contractor	Public	0.480	0.258	0.196
		Client's R	0.422	0.278	0.395
PC43	Public	Client's R	0.012	0.229	1.000
		Contractor	0.392	0.260	0.402
	Client's R	Public	-0.012	0.229	1.000
		Contractor	0.380	0.280	0.533
	Contractor	Public	-0.392	0.260	0.402
		Client's R	-0.380	0.280	0.533
PC44	Public	Client's R	-0.282	0.169	0.297
		Contractor	-0.110	0.192	1.000
	Client's R	Public	0.282	0.169	0.297
		Contractor	0.171	0.207	1.000
	Contractor	Public	0.110	0.192	1.000
		Client's R	-0.171	0.207	1.000
PC45	Public	Client's R	-0.098	0.119	1.000
		Contractor	0.054	0.135	1.000
	Client's R	Public	0.098	0.119	1.000
		Contractor	0.152	0.145	0.892
	Contractor	Public	-0.054	0.135	1.000
		Client's R	-0.152	0.145	0.892

Appendix F2: Post Hoc Multiple Comparisons in Civil Engineering Works (PC)

Multiple Comparisons (Bonferroni)

Dependent variables	Organisation types		Mean Difference	Std. Error	Sig.
PC1	Public	Client's R	-0.4658	0.3243	0.473
		Contractor	-0.1920	0.3407	1.000
	Client's R	Public	0.4658	0.3243	0.473
		Contractor	0.2738	0.3764	1.000
	Contractor	Public	0.1920	0.3407	1.000
		Client's R	-0.2738	0.3764	1.000
PC2	Public	Client's R	-0.1739	0.3903	1.000
		Contractor	-0.3406	0.4100	1.000
	Client's R	Public	0.1739	0.3903	1.000
		Contractor	-0.1667	0.4529	1.000
	Contractor	Public	0.3406	0.4100	1.000
		Client's R	0.1667	0.4529	1.000
PC3	Public	Client's R	-0.9068	0.3607	0.046
		Contractor	-1.0616	0.3789	0.022
	Client's R	Public	0.9068	0.3607	0.046
		Contractor	-0.1548	0.4186	1.000
	Contractor	Public	1.0616	0.3789	0.022
		Client's R	0.1548	0.4186	1.000
PC4	Public	Client's R	0.6646	0.3989	0.308
		Contractor	**1.2920***	0.4191	**0.012**
	Client's R	Public	-0.6646	0.3989	0.308
		Contractor	0.6071	0.4630	0.589
	Contractor	Public	**-1.2920***	0.4191	**0.012**
		Client's R	-0.6071	0.4630	0.589
PC5	Public	Client's R	0.0342	0.2323	1.000
		Contractor	-0.0254	0.2441	1.000
	Client's R	Public	-0.0342	0.2323	1.000
		Contractor	-0.0595	0.2696	1.000
	Contractor	Public	0.0254	0.2441	1.000
		Client's R	0.0595	0.2696	1.000
PC6	Public	Client's R	-0.0807	0.2321	1.000
		Contractor	-0.0688	0.2438	1.000
	Client's R	Public	0.0807	0.2321	1.000
		Contractor	0.0119	0.2693	1.000
	Contractor	Public	0.0688	0.2438	1.000
		Client's R	-0.0119	0.2693	1.000
PC7	Public	Client's R	0.0497	0.2111	1.000
		Contractor	0.1449	0.2217	1.000
	Client's R	Public	-0.0497	0.2111	1.000
		Contractor	0.0952	0.2450	1.000
	Contractor	Public	-0.1449	0.2217	1.000
		Client's R	-0.0952	0.2450	1.000
PC8	Public	Client's R	0.1366	0.2221	1.000
		Contractor	-0.1014	0.2333	1.000
	Client's R	Public	-0.1366	0.2221	1.000
		Contractor	-0.2381	0.2578	1.000
	Contractor	Public	0.1014	0.2333	1.000
		Client's R	0.2381	0.2578	1.000
PC9	Public	Client's R	0.1480	0.2567	1.000
		Contractor	0.1630	0.2697	1.000
	Client's R	Public	-0.1480	0.2567	1.000
		Contractor	0.0150	0.2980	1.000
	Contractor	Public	-0.1630	0.2697	1.000
		Client's R	-0.0150	0.2980	1.000
PC10	Public	Client's R	0.0590	0.3179	1.000
		Contractor	0.0471	0.3339	1.000
	Client's R	Public	-0.0590	0.3179	1.000
		Contractor	-0.0119	0.3689	1.000
	Contractor	Public	-0.0471	0.3339	1.000
		Client's R	0.0119	0.3689	1.000
PC11	Public	Client's R	-0.3602	0.3261	0.825
		Contractor	-0.2924	0.3426	1.000
	Client's R	Public	0.3602	0.3261	0.825
		Contractor	0.0679	0.3784	1.000
	Contractor	Public	0.2924	0.3426	1.000
		Client's R	-0.0679	0.3784	1.000
PC12	Public	Client's R	-0.2112	0.3249	1.000

		Contractor	-0.1993	0.3413	1.000
	Client's R	Public	0.2112	0.3249	1.000
		Contractor	0.0119	0.3771	1.000
	Contractor	Public	0.1993	0.3413	1.000
		Client's R	-0.0119	0.3771	1.000
PC13	Public	Client's R	0.3230	0.3715	1.000
		Contractor	-0.3080	0.3903	1.000
	Client's R	Public	-0.3230	0.3715	1.000
		Contractor	-0.6310	0.4311	0.450
	Contractor	Public	0.3080	0.3903	1.000
		Client's R	0.6310	0.4311	0.450
PC14	Public	Client's R	0.2112	0.1803	0.742
		Contractor	**0.625***	0.1894	**0.006**
	Client's R	Public	-0.2112	0.1803	0.742
		Contractor	0.4048	0.2092	0.178
	Contractor	Public	**-0.625***	0.1894	**0.006**
		Client's R	-0.4048	0.2092	0.178
PC15	Public	Client's R	0.4534	0.2118	0.113
		Contractor	0.0725	0.2225	1.000
	Client's R	Public	-0.4534	0.2118	0.113
		Contractor	-0.3810	0.2458	0.384
	Contractor	Public	-0.0725	0.2225	1.000
		Client's R	0.3810	0.2458	0.384
PC16	Public	Client's R	0.4099	0.1896	0.108
		Contractor	0.0290	0.1992	1.000
	Client's R	Public	-0.4099	0.1896	0.108
		Contractor	-0.3810	0.2201	0.270
	Contractor	Public	-0.0290	0.1992	1.000
		Client's R	0.3810	0.2201	0.270
PC17	Public	Client's R	0.2326	0.3062	1.000
		Contractor	-0.1007	0.3217	1.000
	Client's R	Public	-0.2326	0.3062	1.000
		Contractor	-0.3333	0.3554	1.000
	Contractor	Public	0.1007	0.3217	1.000
		Client's R	0.3333	0.3554	1.000
PC18	Public	Client's R	0.1522	0.3568	1.000
		Contractor	0.4022	0.3748	0.867
	Client's R	Public	-0.1522	0.3568	1.000
		Contractor	0.2500	0.4141	1.000
	Contractor	Public	-0.4022	0.3748	0.867
		Client's R	-0.2500	0.4141	1.000
PC19	Public	Client's R	-0.0963	0.3183	1.000
		Contractor	-0.3225	0.3344	1.000
	Client's R	Public	0.0963	0.3183	1.000
		Contractor	-0.2262	0.3694	1.000
	Contractor	Public	0.3225	0.3344	1.000
		Client's R	0.2262	0.3694	1.000
PC20	Public	Client's R	**-1.1890***	0.3789	**0.011**
		Contractor	-0.5533	0.3981	0.514
	Client's R	Public	**1.1890***	0.3789	**0.011**
		Contractor	0.6036	0.4398	0.530
	Contractor	Public	0.5533	0.3981	0.514
		Client's R	-0.6036	0.4398	0.530
PC21	Public	Client's R	-0.0280	0.2938	1.000
		Contractor	**1.3750***	0.3086	**0.000**
	Client's R	Public	0.0280	0.2938	1.000
		Contractor	**1.4048***	0.3409	**0.000**
	Contractor	Public	**-1.3750***	0.3086	**0.000**
		Client's R	**-1.4048***	0.3409	**0.000**
PC22	Public	Client's R	-0.6335	0.2691	0.069
		Contractor	-0.4312	0.2827	0.402
	Client's R	Public	0.6335	0.2691	0.069
		Contractor	0.2024	0.3123	1.000
	Contractor	Public	0.4312	0.2827	0.402
		Client's R	-0.2024	0.3123	1.000
PC23	Public	Client's R	-0.2888	0.3020	1.000
		Contractor	-0.3841	0.3172	0.697
	Client's R	Public	0.2888	0.3020	1.000
		Contractor	-0.0952	0.3505	1.000
	Contractor	Public	0.3841	0.3172	0.697
		Client's R	0.0952	0.3505	1.000
PC24	Public	Client's R	-0.4161	0.2880	0.466
		Contractor	-0.2846	0.3025	1.000
	Client's R	Public	0.4161	0.2880	0.466
		Contractor	0.1315	0.3342	1.000

	Contractor	Public	0.2846	0.3025	1.000
		Client's R	-0.1315	0.3342	1.000
PC25	Public	Client's R	-0.4099	0.3216	0.626
		Contractor	-0.5290	0.3378	0.373
	Client's R	Public	0.4099	0.3216	0.626
		Contractor	-0.1190	0.3732	1.000
	Contractor	Public	0.5290	0.3378	0.373
		Client's R	0.1190	0.3732	1.000
PC26	Public	Client's R	0.2671	0.2955	1.000
		Contractor	0.0290	0.3105	1.000
	Client's R	Public	-0.2671	0.2955	1.000
		Contractor	-0.2381	0.3430	1.000
	Contractor	Public	-0.0290	0.3105	1.000
		Client's R	0.2381	0.3430	1.000
PC27	Public	Client's R	-0.0942	0.3036	1.000
		Contractor	0.1326	0.3190	1.000
	Client's R	Public	0.0942	0.3036	1.000
		Contractor	0.2268	0.3524	1.000
	Contractor	Public	-0.1326	0.3190	1.000
		Client's R	-0.2268	0.3524	1.000
PC28	Public	Client's R	-0.3540	0.2140	0.315
		Contractor	-0.2826	0.2249	0.646
	Client's R	Public	0.3540	0.2140	0.315
		Contractor	0.0714	0.2484	1.000
	Contractor	Public	0.2826	0.2249	0.646
		Client's R	-0.0714	0.2484	1.000
PC29	Public	Client's R	-0.5081	0.2848	0.243
		Contractor	-0.5319	0.2992	0.246
	Client's R	Public	0.5081	0.2848	0.243
		Contractor	-0.0238	0.3305	1.000
	Contractor	Public	0.5319	0.2992	0.246
		Client's R	0.0238	0.3305	1.000
PC30	Public	Client's R	-0.5000	0.3381	0.438
		Contractor	-0.2500	0.3551	1.000
	Client's R	Public	0.5000	0.3381	0.438
		Contractor	0.2500	0.3923	1.000
	Contractor	Public	0.2500	0.3551	1.000
		Client's R	-0.2500	0.3923	1.000
PC31	Public	Client's R	-0.4320	0.3391	0.627
		Contractor	-0.3297	0.3563	1.000
	Client's R	Public	0.4320	0.3391	0.627
		Contractor	0.1023	0.3936	1.000
	Contractor	Public	0.3297	0.3563	1.000
		Client's R	-0.1023	0.3936	1.000
PC32	Public	Client's R	-0.6056	0.3242	0.205
		Contractor	-0.6413	0.3406	0.198
	Client's R	Public	0.6056	0.3242	0.205
		Contractor	-0.0357	0.3763	1.000
	Contractor	Public	0.6413	0.3406	0.198
		Client's R	0.0357	0.3763	1.000
PC33	Public	Client's R	-0.4037	0.2168	0.207
		Contractor	-0.5942	0.2278	0.037
	Client's R	Public	0.4037	0.2168	0.207
		Contractor	-0.1905	0.2516	1.000
	Contractor	Public	0.5942	0.2278	0.037
		Client's R	0.1905	0.2516	1.000
PC34	Public	Client's R	-0.3950	0.3006	0.586
		Contractor	-0.4270	0.3158	0.549
	Client's R	Public	0.3950	0.3006	0.586
		Contractor	-0.0320	0.3489	1.000
	Contractor	Public	0.4270	0.3158	0.549
		Client's R	0.0320	0.3489	1.000
PC35	Public	Client's R	-0.3696	0.3547	0.909
		Contractor	-0.6196	0.3726	0.309
	Client's R	Public	0.3696	0.3547	0.909
		Contractor	-0.2500	0.4116	1.000
	Contractor	Public	0.6196	0.3726	0.309
		Client's R	0.2500	0.4116	1.000
PC36	Public	Client's R	-0.5167	0.2633	0.167
		Contractor	-0.5217	0.2766	0.197
	Client's R	Public	0.5167	0.2633	0.167
		Contractor	-0.0050	0.3055	1.000
	Contractor	Public	0.5217	0.2766	0.197
		Client's R	0.0050	0.3055	1.000
PC37	Public	Client's R	-0.2298	0.2847	1.000

		Contractor	-0.6703	0.2991	0.090
	Client's R	Public	0.2298	0.2847	1.000
		Contractor	-0.4405	0.3305	0.567
	Contractor	Public	0.6703	0.2991	0.090
		Client's R	0.4405	0.3305	0.567
PC38	Public	Client's R	-0.8075	0.3142	0.040
		Contractor	-0.4384	0.3300	0.572
	Client's R	Public	0.8075	0.3142	0.040
		Contractor	0.3690	0.3646	0.950
	Contractor	Public	0.4384	0.3300	0.572
		Client's R	-0.3690	0.3646	0.950
PC39	Public	Client's R	-0.6053	0.3183	0.190
		Contractor	0.2638	0.3343	1.000
	Client's R	Public	0.6053	0.3183	0.190
		Contractor	0.8690	0.3693	0.069
	Contractor	Public	-0.2638	0.3343	1.000
		Client's R	-0.8690	0.3693	0.069
PC40	Public	Client's R	-0.1429	0.2813	1.000
		Contractor	-0.6222	0.2956	0.122
	Client's R	Public	0.1429	0.2813	1.000
		Contractor	-0.4793	0.3265	0.447
	Contractor	Public	0.6222	0.2956	0.122
		Client's R	0.4793	0.3265	0.447
PC41	Public	Client's R	-0.7503	0.3282	0.081
		Contractor	-0.7384	0.3448	0.113
	Client's R	Public	0.7503	0.3282	0.081
		Contractor	0.0119	0.3809	1.000
	Contractor	Public	0.7384	0.3448	0.113
		Client's R	-0.0119	0.3809	1.000
PC42	Public	Client's R	0.1380	0.3617	1.000
		Contractor	-0.3413	0.3800	1.000
	Client's R	Public	-0.1380	0.3617	1.000
		Contractor	-0.4793	0.4198	0.778
	Contractor	Public	0.3413	0.3800	1.000
		Client's R	0.4793	0.4198	0.778
PC43	Public	Client's R	0.3808	0.2934	0.602
		Contractor	0.6377	0.3082	0.133
	Client's R	Public	-0.3808	0.2934	0.602
		Contractor	0.2569	0.3405	1.000
	Contractor	Public	-0.6377	0.3082	0.133
		Client's R	-0.2569	0.3405	1.000
PC44	Public	Client's R	-0.1810	0.2252	1.000
		Contractor	-0.2862	0.2365	0.697
	Client's R	Public	0.1810	0.2252	1.000
		Contractor	-0.1052	0.2613	1.000
	Contractor	Public	0.2862	0.2365	0.697
		Client's R	0.1052	0.2613	1.000
PC45	Public	Client's R	-0.1803	0.1653	0.844
		Contractor	-0.0837	0.1737	1.000
	Client's R	Public	0.1803	0.1653	0.844
		Contractor	0.0966	0.1919	1.000
	Contractor	Public	0.0837	0.1737	1.000
		Client's R	-0.0966	0.1919	1.000

Appendix G: Non-Parametric Tests for Building and Civil Engineering Works (PSC)

	Building			Civil E.		
	Chi-Square	*df*	*Sig.*	*Chi-Square*	*df*	*Sig.*
PSC1	0.989	2	0.610	0.856	2	0.652
PSC2	2.627	2	0.269	1.387	2	0.500
PSC3	2.699	2	0.259	0.676	2	0.713
PSC4	2.866	2	0.239	6.302	2	***0.043**
PSC5	1.007	2	0.605	1.016	2	0.602
PSC6	0.475	2	0.789	0.409	2	0.815
PSC7	6.612	2	***0.037**	1.882	2	0.390
PSC8	3.018	2	0.221	0.319	2	0.853
PSC9	0.066	2	0.967	0.826	2	0.662
PSC10	4.209	2	0.122	4.375	2	0.112
PSC11	3.366	2	0.186	2.892	2	0.236
PSC12	0.433	2	0.805	0.261	2	0.878
PSC13	9.496	2	***0.009**	5.885	2	0.053
PSC14	1.467	2	0.480	1.236	2	0.539
PSC15	6.834	2	***0.033**	0.274	2	0.872
PSC16	9.438	2	***0.009**	0.324	2	0.850
PSC17	4.680	2	0.096	2.948	2	0.229
PSC18	11.308	2	***0.004**	1.244	2	0.537
PSC19	12.635	2	***0.002**	8.286	2	***0.016**
PSC20	2.509	2	0.285	4.903	2	0.086
PSC21	1.208	2	0.547	1.307	2	0.520
PSC22	2.786	2	0.248	1.235	2	0.539
PSC23	3.377	2	0.185	2.196	2	0.334
PSC24	4.570	2	0.102	1.521	2	0.468
PSC25	0.505	2	0.777	4.441	2	0.109
PSC26	5.748	2	0.056	0.066	2	0.967
PSC27	4.820	2	0.090	2.013	2	0.366
PSC28	5.200	2	0.074	11.864	2	***0.003**
PSC29	3.846	2	0.146	6.205	2	***0.045**
PSC30	0.213	2	0.899	0.395	2	0.821
PSC31	0.126	2	0.939	0.658	2	0.720
PSC32	11.258	2	***0.004**	6.950	2	***0.031**

* *Significant at 0.05 levels*

Appendix H1: Parametric Test for Building Works (PSC)

		Sum of Squares	*df*	*Mean Square*	*F*	*Sig.*
PSC1	Between Groups	0.637	2	0.318	0.386	0.681
	Within Groups	88.359	107	0.826		
	Total	88.996	109			
PSC2	Between Groups	2.089	2	1.045	1.654	0.196
	Within Groups	67.578	107	0.632		
	Total	69.667	109			
PSC3	Between Groups	3.035	2	1.518	1.761	0.177
	Within Groups	92.193	107	0.862		
	Total	95.228	109			
PSC4	Between Groups	1.937	2	0.968	1.621	0.202
	Within Groups	63.919	107	0.597		
	Total	65.856	109			
PSC5	Between Groups	1.002	2	0.501	0.423	0.656
	Within Groups	126.674	107	1.184		
	Total	127.675	109			
PSC6	Between Groups	0.423	2	0.212	0.190	0.827
	Within Groups	119.230	107	1.114		
	Total	119.654	109			
PSC7	Between Groups	7.408	2	3.704	3.330	*0.040
	Within Groups	119.009	107	1.112		
	Total	126.418	109			
PSC8	Between Groups	3.940	2	1.970	1.411	0.248
	Within Groups	149.399	107	1.396		
	Total	153.339	109			
PSC9	Between Groups	0.158	2	0.079	0.099	0.906
	Within Groups	85.560	107	0.800		
	Total	85.718	109			
PSC10	Between Groups	3.726	2	1.863	2.395	0.096
	Within Groups	83.228	107	0.778		
	Total	86.955	109			
PSC11	Between Groups	3.118	2	1.559	1.425	0.245
	Within Groups	117.021	107	1.094		
	Total	120.139	109			
PSC12	Between Groups	0.651	2	0.326	0.306	0.737
	Within Groups	114.020	107	1.066		
	Total	114.671	109			
PSC13	Between Groups	4.604	2	2.302	5.256	*0.007
	Within Groups	46.862	107	0.438		
	Total	51.466	109			
PSC14	Between Groups	1.401	2	0.700	0.666	0.516
	Within Groups	112.563	107	1.052		
	Total	113.964	109			
PSC15	Between Groups	7.806	2	3.903	3.899	*0.023
	Within Groups	107.112	107	1.001		
	Total	114.918	109			
PSC16	Between Groups	11.437	2	5.718	4.970	*0.009
	Within Groups	123.118	107	1.151		
	Total	134.555	109			
PSC17	Between Groups	4.946	2	2.473	2.440	0.092
	Within Groups	108.472	107	1.014		
	Total	113.418	109			
PSC18	Between Groups	11.530	2	5.765	5.546	*0.005
	Within Groups	111.236	107	1.040		
	Total	122.766	109			
PSC19	Between Groups	15.354	2	7.677	6.816	*0.002
	Within Groups	120.512	107	1.126		
	Total	135.866	109			
PSC20	Between Groups	3.339	2	1.669	1.165	0.316
	Within Groups	153.309	107	1.433		
	Total	156.648	109			
PSC21	Between Groups	0.808	2	0.404	0.384	0.682
	Within Groups	112.510	107	1.051		
	Total	113.318	109			
PSC22	Between Groups	1.612	2	0.806	1.011	0.367
	Within Groups	85.343	107	0.798		
	Total	86.955	109			
PSC23	Between Groups	2.714	2	1.357	1.410	0.249
	Within Groups	102.958	107	0.962		
	Total	105.673	109			

PSC24	Between Groups	3.594	2	1.797	2.334	0.102
	Within Groups	82.394	107	0.770		
	Total	85.988	109			
PSC25	Between Groups	0.766	2	0.383	0.450	0.639
	Within Groups	90.996	107	0.850		
	Total	91.762	109			
PSC26	Between Groups	3.360	2	1.680	2.591	0.080
	Within Groups	69.381	107	0.648		
	Total	72.741	109			
PSC27	Between Groups	5.381	2	2.691	3.015	0.053
	Within Groups	95.489	107	0.892		
	Total	100.870	109			
PSC28	Between Groups	2.377	2	1.188	2.981	0.055
	Within Groups	42.656	107	0.399		
	Total	45.032	109			
PSC29	Between Groups	1.311	2	0.656	1.503	0.227
	Within Groups	46.662	107	0.436		
	Total	47.973	109			
PSC30	Between Groups	0.086	2	0.043	0.066	0.936
	Within Groups	68.849	107	0.643		
	Total	68.934	109			
PSC31	Between Groups	0.087	2	0.044	0.179	0.837
	Within Groups	26.099	107	0.244		
	Total	26.186	109			
PSC32	Between Groups	6.004	2	3.002	4.791	***0.010**
	Within Groups	67.042	107	0.627		
	Total	73.04606	109			

* *Significant at 0.05 leves*

Appendix H2: Parametric Test for Civil Engineering Works (PSC)

		Sum of Squares	*df*	*Mean Square*	*F*	*Sig.*
PSC1	Between Groups	0.433	2	0.217	0.249	0.781
	Within Groups	44.400	51	0.871		
	Total	44.833	53			
PSC2	Between Groups	0.773	2	0.387	0.678	0.512
	Within Groups	29.097	51	0.571		
	Total	29.870	53			
PSC3	Between Groups	0.563	2	0.281	0.370	0.692
	Within Groups	38.721	51	0.759		
	Total	39.283	53			
PSC4	Between Groups	3.029	2	1.515	3.407	***0.041**
	Within Groups	22.674	51	0.445		
	Total	25.704	53			
PSC5	Between Groups	1.080	2	0.540	0.464	0.631
	Within Groups	59.290	51	1.163		
	Total	60.370	53			
PSC6	Between Groups	0.064	2	0.032	0.033	0.968
	Within Groups	49.862	51	0.978		
	Total	49.926	53			
PSC7	Between Groups	1.729	2	0.864	0.794	0.458
	Within Groups	55.530	51	1.089		
	Total	57.259	53			
PSC8	Between Groups	0.226	2	0.113	0.086	0.918
	Within Groups	67.108	51	1.316		
	Total	67.333	53			
PSC9	Between Groups	0.782	2	0.391	0.538	0.587
	Within Groups	37.089	51	0.727		
	Total	37.870	53			
PSC10	Between Groups	3.027	2	1.514	2.273	0.113
	Within Groups	33.954	51	0.666		
	Total	36.981	53			
PSC11	Between Groups	2.186	2	1.093	1.115	0.336
	Within Groups	50.022	51	0.981		
	Total	52.208	53			
PSC12	Between Groups	0.260	2	0.130	0.126	0.882
	Within Groups	52.762	51	1.035		
	Total	53.022	53			
PSC13	Between Groups	2.047	2	1.023	3.244	***0.047**
	Within Groups	16.088	51	0.315		
	Total	18.134	53			
PSC14	Between Groups	1.393	2	0.696	0.583	0.562
	Within Groups	60.922	51	1.195		
	Total	62.315	53			
PSC15	Between Groups	0.518	2	0.259	0.175	0.840
	Within Groups	75.630	51	1.483		
	Total	76.148	53			
PSC16	Between Groups	0.609	2	0.304	0.174	0.841
	Within Groups	89.317	51	1.751		
	Total	89.926	53			
PSC17	Between Groups	3.895	2	1.948	1.655	0.201
	Within Groups	60.030	51	1.177		
	Total	63.926	53			
PSC18	Between Groups	1.661	2	0.831	0.556	0.577
	Within Groups	76.164	51	1.493		
	Total	77.825	53			
PSC19	Between Groups	11.915	2	5.957	4.723	***0.013**
	Within Groups	64.330	51	1.261		
	Total	76.245	53			
PSC20	Between Groups	6.991	2	3.496	2.423	0.099
	Within Groups	73.588	51	1.443		
	Total	80.579	53			
PSC21	Between Groups	0.903	2	0.451	0.577	0.565
	Within Groups	39.930	51	0.783		
	Total	40.833	53			
PSC22	Between Groups	0.583	2	0.291	0.694	0.504
	Within Groups	21.417	51	0.420		
	Total	22.000	53			
PSC23	Between Groups	1.658	2	0.829	1.173	0.318

	Within Groups	35.323	50	0.706		
	Total	36.981	52			
PSC24	Between Groups	1.285	2	0.642	0.848	0.434
	Within Groups	38.650	51	0.758		
	Total	39.935	53			
PSC25	Between Groups	3.047	2	1.524	2.252	0.116
	Within Groups	34.501	51	0.676		
	Total	37.548	53			
PSC26	Between Groups	0.056	2	0.028	0.036	0.965
	Within Groups	39.451	51	0.774		
	Total	39.507	53			
PSC27	Between Groups	2.340	2	1.170	1.440	0.246
	Within Groups	41.440	51	0.813		
	Total	43.780	53			
PSC28	Between Groups	4.019	2	2.010	6.918	***0.002**
	Within Groups	14.814	51	0.290		
	Total	18.833	53			
PSC29	Between Groups	2.865	2	1.432	3.569	***0.035**
	Within Groups	20.469	51	0.401		
	Total	23.333	53			
PSC30	Between Groups	0.318	2	0.159	0.199	0.820
	Within Groups	40.671	51	0.797		
	Total	40.989	53			
PSC31	Between Groups	0.464	2	0.232	0.542	0.585
	Within Groups	21.850	51	0.428		
	Total	22.315	53			
PSC32	Between Groups	5.185	2	2.593	3.593	***0.035**
	Within Groups	36.795	51	0.721		
	Between Groups	0.433	2	0.217	0.249	0.781

* *Significant at 0.05 level*

Appendix I: Post Hoc Multi Comparisons in Building Works (PSC)

Multiple Comparisons (Bonferroni)					
Dependent variables	Organisation types		*Mean Difference*	*Std. Error*	*Sig.*
PSC1	Public	Client's R	-0.132	0.199	1.000
		Contractor	0.069	0.228	1.000
	Client's R	Public	0.132	0.199	1.000
		Contractor	0.201	0.244	1.000
	Contractor	Public	-0.069	0.228	1.000
		Client's R	-0.201	0.244	1.000
PSC2	Public	Client's R	-0.285	0.174	0.310
		Contractor	-0.260	0.199	0.580
	Client's R	Public	0.285	0.174	0.310
		Contractor	0.025	0.213	1.000
	Contractor	Public	0.260	0.199	0.580
		Client's R	-0.025	0.213	1.000
PSC3	Public	Client's R	-0.380	0.203	0.192
		Contractor	-0.181	0.232	1.000
	Client's R	Public	0.380	0.203	0.192
		Contractor	0.199	0.249	1.000
	Contractor	Public	0.181	0.232	1.000
		Client's R	-0.199	0.249	1.000
PSC4	Public	Client's R	-0.267	0.169	0.349
		Contractor	0.048	0.194	1.000
	Client's R	Public	0.267	0.169	0.349
		Contractor	0.316	0.207	0.394
	Contractor	Public	-0.048	0.194	1.000
		Client's R	-0.316	0.207	0.394
PSC5	Public	Client's R	0.185	0.238	1.000
		Contractor	0.200	0.272	1.000
	Client's R	Public	-0.185	0.238	1.000
		Contractor	0.015	0.292	1.000
	Contractor	Public	-0.200	0.272	1.000
		Client's R	-0.015	0.292	1.000
PSC6	Public	Client's R	0.045	0.231	1.000
		Contractor	0.163	0.264	1.000
	Client's R	Public	-0.045	0.231	1.000
		Contractor	0.118	0.283	1.000
	Contractor	Public	-0.163	0.264	1.000
		Client's R	-0.118	0.283	1.000
PSC7	Public	Client's R	0.545	0.231	0.059
		Contractor	0.475	0.264	0.225
	Client's R	Public	-0.545	0.231	0.059
		Contractor	-0.071	0.283	1.000
	Contractor	Public	-0.475	0.264	0.225
		Client's R	0.071	0.283	1.000
PSC8	Public	Client's R	0.396	0.258	0.385
		Contractor	0.350	0.296	0.719
	Client's R	Public	-0.396	0.258	0.385
		Contractor	-0.046	0.317	1.000
	Contractor	Public	-0.350	0.296	0.719
		Client's R	0.046	0.317	1.000
PSC9	Public	Client's R	-0.032	0.196	1.000
		Contractor	-0.099	0.224	1.000
	Client's R	Public	0.032	0.196	1.000
		Contractor	-0.067	0.240	1.000
	Contractor	Public	0.099	0.224	1.000
		Client's R	0.067	0.240	1.000
PSC10	Public	Client's R	-0.422	0.193	0.092
		Contractor	-0.177	0.221	1.000
	Client's R	Public	0.422	0.193	0.092
		Contractor	0.245	0.237	0.911
	Contractor	Public	0.177	0.221	1.000
		Client's R	-0.245	0.237	0.911
PSC11	Public	Client's R	-0.338	0.229	0.426
		Contractor	-0.336	0.262	0.608
	Client's R	Public	0.338	0.229	0.426
		Contractor	0.002	0.281	1.000
	Contractor	Public	0.336	0.262	0.608
		Client's R	-0.002	0.281	1.000
PSC12	Public	Client's R	-0.176	0.226	1.000

		Contractor	-0.084	0.259	1.000
	Client's R	Public	0.176	0.226	1.000
		Contractor	0.092	0.277	1.000
	Contractor	Public	0.084	0.259	1.000
		Client's R	-0.092	0.277	1.000
PSC13	Public	Client's R	**-0.418***	0.145	**0.014**
		Contractor	-0.397	0.166	0.055
	Client's R	Public	**0.418***	0.145	**0.014**
		Contractor	0.021	0.178	1.000
	Contractor	Public	0.397	0.166	0.055
		Client's R	-0.021	0.178	1.000
PSC14	Public	Client's R	-0.216	0.224	1.000
		Contractor	0.066	0.257	1.000
	Client's R	Public	0.216	0.224	1.000
		Contractor	0.282	0.275	0.924
	Contractor	Public	-0.066	0.257	1.000
		Client's R	-0.282	0.275	0.924
PSC15	Public	Client's R	-0.508	0.219	0.067
		Contractor	-0.569	0.251	0.076
	Client's R	Public	0.508	0.219	0.067
		Contractor	-0.061	0.269	1.000
	Contractor	Public	0.569	0.251	0.076
		Client's R	0.061	0.269	1.000
PSC16	Public	Client's R	-0.661	0.235	0.017
		Contractor	-0.621	0.269	0.068
	Client's R	Public	0.661	0.235	0.017
		Contractor	0.040	0.288	1.000
	Contractor	Public	0.621	0.269	0.068
		Client's R	-0.040	0.288	1.000
PSC17	Public	Client's R	-0.346	0.220	0.358
		Contractor	-0.506	0.252	0.142
	Client's R	Public	0.346	0.220	0.358
		Contractor	-0.160	0.270	1.000
	Contractor	Public	0.506	0.252	0.142
		Client's R	0.160	0.270	1.000
PSC18	Public	Client's R	**0.694***	0.223	**0.007**
		Contractor	0.562	0.255	0.089
	Client's R	Public	**-0.694***	0.223	**0.007**
		Contractor	-0.132	0.274	1.000
	Contractor	Public	-0.562	0.255	0.089
		Client's R	0.132	0.274	1.000
PSC19	Public	Client's R	-0.589	0.232	0.038
		Contractor	**-0.904***	0.266	**0.003**
	Client's R	Public	0.589	0.232	0.038
		Contractor	-0.316	0.285	0.812
	Contractor	Public	**0.904***	0.266	**0.003**
		Client's R	0.316	0.285	0.812
PSC20	Public	Client's R	-0.060	0.262	1.000
		Contractor	-0.448	0.300	0.415
	Client's R	Public	0.060	0.262	1.000
		Contractor	-0.388	0.321	0.691
	Contractor	Public	0.448	0.300	0.415
		Client's R	0.388	0.321	0.691
PSC21	Public	Client's R	-0.136	0.224	1.000
		Contractor	0.098	0.257	1.000
	Client's R	Public	0.136	0.224	1.000
		Contractor	0.234	0.275	1.000
	Contractor	Public	-0.098	0.257	1.000
		Client's R	-0.234	0.275	1.000
PSC22	Public	Client's R	0.088	0.195	1.000
		Contractor	0.318	0.224	0.475
	Client's R	Public	-0.088	0.195	1.000
		Contractor	0.230	0.240	1.000
	Contractor	Public	-0.318	0.224	0.475
		Client's R	-0.230	0.240	1.000
PSC23	Public	Client's R	0.334	0.214	0.369
		Contractor	0.280	0.246	0.770
	Client's R	Public	-0.334	0.214	0.369
		Contractor	-0.053	0.263	1.000
	Contractor	Public	-0.280	0.246	0.770
		Client's R	0.053	0.263	1.000
PSC24	Public	Client's R	0.341	0.192	0.236
		Contractor	0.390	0.220	0.235
	Client's R	Public	-0.341	0.192	0.236
		Contractor	0.050	0.236	1.000

	Contractor	Public	-0.390	0.220	0.235
		Client's R	-0.050	0.236	1.000
PSC25	Public	Client's R	-0.081	0.202	1.000
		Contractor	0.153	0.231	1.000
	Client's R	Public	0.081	0.202	1.000
		Contractor	0.234	0.248	1.000
	Contractor	Public	-0.153	0.231	1.000
		Client's R	-0.234	0.248	1.000
PSC26	Public	Client's R	0.392	0.176	0.084
		Contractor	0.245	0.202	0.681
	Client's R	Public	-0.392	0.176	0.084
		Contractor	-0.147	0.216	1.000
	Contractor	Public	-0.245	0.202	0.681
		Client's R	0.147	0.216	1.000
PSC27	Public	Client's R	-0.464	0.207	0.080
		Contractor	-0.406	0.237	0.267
	Client's R	Public	0.464	0.207	0.080
		Contractor	0.058	0.254	1.000
	Contractor	Public	0.406	0.237	0.267
		Client's R	-0.058	0.254	1.000
PSC28	Public	Client's R	-0.172	0.205	1.000
		Contractor	-0.579	0.235	0.046
	Client's R	Public	0.172	0.205	1.000
		Contractor	-0.407	0.252	0.325
	Contractor	Public	0.579	0.235	0.046
		Client's R	0.407	0.252	0.325
PSC29	Public	Client's R	-0.427	0.199	0.102
		Contractor	-0.957	0.228	0.021
	Client's R	Public	0.427	0.199	0.102
		Contractor	-0.530	0.244	0.096
	Contractor	Public	0.957	0.228	0.021
		Client's R	0.530	0.244	0.096
PSC30	Public	Client's R	-0.117	0.203	1.000
		Contractor	-0.543	0.232	0.063
	Client's R	Public	0.117	0.203	1.000
		Contractor	-0.427	0.249	0.268
	Contractor	Public	0.543	0.232	0.063
		Client's R	0.427	0.249	0.268
PSC31	Public	Client's R	-0.217	0.212	0.926
		Contractor	-1.313	0.243	0.019
	Client's R	Public	0.217	0.212	0.926
		Contractor	-1.096	0.261	0.018
	Contractor	Public	1.313	0.243	0.019
		Client's R	1.096	0.261	0.018
PSC32	Public	Client's R	0.066	0.216	1.000
		Contractor	-1.097	0.247	0.018
	Client's R	Public	-0.066	0.216	1.000
		Contractor	-1.163	0.265	0.019
	Contractor	Public	1.097	0.247	0.018
		Client's R	1.163	0.265	0.019

* *The mean difference is significant at the .017 level.*

Appendix J: Post Hoc Multi Comparisons in Civil Engineering Works (PSC)

Multiple Comparisons (Bonferroni)

Dependent variables	Organisation types		*Mean Difference*	*Std. Error*	*Sig.*
PSC1	Public	Client's R	-0.200	0.305	1.0000
		Contractor	0.000	0.311	1.0000
	Client's R	Public	0.200	0.305	1.0000
		Contractor	0.200	0.347	1.0000
	Contractor	Public	0.000	0.311	1.0000
		Client's R	-0.200	0.347	1.0000
PSC2	Public	Client's R	-0.280	0.247	0.7850
		Contractor	-0.166	0.252	1.0000
	Client's R	Public	0.280	0.247	0.7850
		Contractor	0.114	0.281	1.0000
	Contractor	Public	0.166	0.252	1.0000
		Client's R	-0.114	0.281	1.0000
PSC3	Public	Client's R	-0.159	0.285	1.0000
		Contractor	0.117	0.291	1.0000
	Client's R	Public	0.159	0.285	1.0000
		Contractor	0.276	0.324	1.0000
	Contractor	Public	-0.117	0.291	1.0000
		Client's R	-0.276	0.324	1.0000
PSC4	Public	Client's R	-0.560	0.218	0.0392
		Contractor	-0.303	0.223	0.5388
	Client's R	Public	0.560	0.218	0.0392
		Contractor	0.257	0.248	0.9128
	Contractor	Public	0.303	0.223	0.5388
		Client's R	-0.257	0.248	0.9128
PSC5	Public	Client's R	0.333	0.352	1.0000
		Contractor	0.186	0.360	1.0000
	Client's R	Public	-0.333	0.352	1.0000
		Contractor	-0.148	0.401	1.0000
	Contractor	Public	-0.186	0.360	1.0000
		Client's R	0.148	0.401	1.0000
PSC6	Public	Client's R	0.067	0.323	1.0000
		Contractor	0.071	0.330	1.0000
	Client's R	Public	-0.067	0.323	1.0000
		Contractor	0.005	0.367	1.0000
	Contractor	Public	-0.071	0.330	1.0000
		Client's R	-0.005	0.367	1.0000
PSC7	Public	Client's R	0.413	0.341	0.6923
		Contractor	0.266	0.348	1.0000
	Client's R	Public	-0.413	0.341	0.6923
		Contractor	-0.148	0.388	1.0000
	Contractor	Public	-0.266	0.348	1.0000
		Client's R	0.148	0.388	1.0000
PSC8	Public	Client's R	0.093	0.375	1.0000
		Contractor	-0.083	0.383	1.0000
	Client's R	Public	-0.093	0.375	1.0000
		Contractor	-0.176	0.426	1.0000
	Contractor	Public	0.083	0.383	1.0000
		Client's R	0.176	0.426	1.0000
PSC9	Public	Client's R	0.160	0.279	1.0000
		Contractor	-0.169	0.285	1.0000
	Client's R	Public	-0.160	0.279	1.0000
		Contractor	-0.329	0.317	0.9141
	Contractor	Public	0.169	0.285	1.0000
		Client's R	0.329	0.317	0.9141
PSC10	Public	Client's R	-0.520	0.266	0.1696
		Contractor	0.023	0.272	1.0000
	Client's R	Public	0.520	0.266	0.1696
		Contractor	0.543	0.303	0.2380

	Contractor	Public	-0.023	0.272	1.0000
		Client's R	-0.543	0.303	0.2380
PSC11	Public	Client's R	-0.473	0.323	0.4485
		Contractor	-0.269	0.331	1.0000
	Client's R	Public	0.473	0.323	0.4485
		Contractor	0.205	0.368	1.0000
	Contractor	Public	0.269	0.331	1.0000
		Client's R	-0.205	0.368	1.0000
PSC12	Public	Client's R	-0.166	0.332	1.0000
		Contractor	-0.071	0.340	1.0000
	Client's R	Public	0.166	0.332	1.0000
		Contractor	0.095	0.378	1.0000
	Contractor	Public	0.071	0.340	1.0000
		Client's R	-0.095	0.378	1.0000
PSC13	Public	Client's R	-0.153	0.183	1.0000
		Contractor	-0.477	0.187	0.0420
	Client's R	Public	0.153	0.183	1.0000
		Contractor	-0.324	0.209	0.3809
	Contractor	Public	0.477	0.187	0.0420
		Client's R	0.324	0.209	0.3809
PSC14	Public	Client's R	-0.227	0.357	1.0000
		Contractor	0.211	0.365	1.0000
	Client's R	Public	0.227	0.357	1.0000
		Contractor	0.438	0.406	0.8575
	Contractor	Public	-0.211	0.365	1.0000
		Client's R	-0.438	0.406	0.8575
PSC15	Public	Client's R	-0.187	0.398	1.0000
		Contractor	-0.206	0.407	1.0000
	Client's R	Public	0.187	0.398	1.0000
		Contractor	-0.019	0.453	1.0000
	Contractor	Public	0.206	0.407	1.0000
		Client's R	0.019	0.453	1.0000
PSC16	Public	Client's R	-0.040	0.432	1.0000
		Contractor	-0.254	0.442	1.0000
	Client's R	Public	0.040	0.432	1.0000
		Contractor	-0.214	0.492	1.0000
	Contractor	Public	0.254	0.442	1.0000
		Client's R	0.214	0.492	1.0000
PSC17	Public	Client's R	-0.453	0.354	0.6197
		Contractor	-0.606	0.362	0.3016
	Client's R	Public	0.453	0.354	0.6197
		Contractor	-0.152	0.403	1.0000
	Contractor	Public	0.606	0.362	0.3016
		Client's R	0.152	0.403	1.0000
PSC18	Public	Client's R	0.417	0.399	0.9015
		Contractor	0.208	0.408	1.0000
	Client's R	Public	-0.417	0.399	0.9015
		Contractor	-0.210	0.454	1.0000
	Contractor	Public	-0.208	0.408	1.0000
		Client's R	0.210	0.454	1.0000
PSC19	Public	Client's R	-1.047	0.367	0.0187
		Contractor	0.006	0.375	1.0000
	Client's R	Public	1.047	0.367	0.0187
		Contractor	1.052	0.417	0.0446
	Contractor	Public	-0.006	0.375	1.0000
		Client's R	-1.052	0.417	0.0446
PSC20	Public	Client's R	-0.553	0.392	0.4934
		Contractor	0.423	0.401	0.8898
	Client's R	Public	0.553	0.392	0.4934
		Contractor	0.976	0.446	0.1001
	Contractor	Public	-0.423	0.401	0.8898
		Client's R	-0.976	0.446	0.1001
PSC21	Public	Client's R	-0.213	0.289	1.0000
		Contractor	0.134	0.295	1.0000

	Client's R	Public	0.213	0.289	1.0000
		Contractor	0.348	0.329	0.8862
	Contractor	Public	-0.134	0.295	1.0000
		Client's R	-0.348	0.329	0.8862
PSC22	Public	Client's R	0.240	0.212	0.7863
		Contractor	0.154	0.216	1.0000
	Client's R	Public	-0.240	0.212	0.7863
		Contractor	-0.086	0.241	1.0000
	Contractor	Public	-0.154	0.216	1.0000
		Client's R	0.086	0.241	1.0000
PSC23	Public	Client's R	0.400	0.275	0.4540
		Contractor	0.277	0.287	1.0000
	Client's R	Public	-0.400	0.275	0.4540
		Contractor	-0.123	0.318	1.0000
	Contractor	Public	-0.277	0.287	1.0000
		Client's R	0.123	0.318	1.0000
PSC24	Public	Client's R	0.084	0.284	1.0000
		Contractor	0.374	0.291	0.6107
	Client's R	Public	-0.084	0.284	1.0000
		Contractor	0.290	0.324	1.0000
	Contractor	Public	-0.374	0.291	0.6107
		Client's R	-0.290	0.324	1.0000
PSC25	Public	Client's R	-0.339	0.269	0.6368
		Contractor	-0.563	0.275	0.1365
	Client's R	Public	0.339	0.269	0.6368
		Contractor	-0.224	0.306	1.0000
	Contractor	Public	0.563	0.275	0.1365
		Client's R	0.224	0.306	1.0000
PSC26	Public	Client's R	-0.064	0.287	1.0000
		Contractor	0.017	0.294	1.0000
	Client's R	Public	0.064	0.287	1.0000
		Contractor	0.081	0.327	1.0000
	Contractor	Public	-0.017	0.294	1.0000
		Client's R	-0.081	0.327	1.0000
PSC27	Public	Client's R	-0.332	0.294	0.7942
		Contractor	-0.479	0.301	0.3518
	Client's R	Public	0.332	0.294	0.7942
		Contractor	-0.147	0.335	1.0000
	Contractor	Public	0.479	0.301	0.3518
		Client's R	0.147	0.335	1.0000
PSC28	Public	Client's R	-0.400	0.176	0.0819
		Contractor	**-0.643***	0.180	**0.0023**
	Client's R	Public	0.400	0.176	0.0819
		Contractor	-0.243	0.200	0.6926
	Contractor	Public	**0.643***	0.180	**0.0023**
		Client's R	0.243	0.200	0.6926
PSC29	Public	Client's R	-0.320	0.207	0.3844
		Contractor	-0.549	0.211	0.0371
	Client's R	Public	0.320	0.207	0.3844
		Contractor	-0.229	0.235	1.0000
	Contractor	Public	0.549	0.211	0.0371
		Client's R	0.229	0.235	1.0000
PSC30	Public	Client's R	-0.044	0.292	1.0000
		Contractor	-0.186	0.298	1.0000
	Client's R	Public	0.044	0.292	1.0000
		Contractor	-0.143	0.332	1.0000
	Contractor	Public	0.186	0.298	1.0000
		Client's R	0.143	0.332	1.0000
PSC31	Public	Client's R	-0.107	0.214	1.0000
		Contractor	-0.226	0.218	0.9194
	Client's R	Public	0.107	0.214	1.0000
		Contractor	-0.119	0.243	1.0000
	Contractor	Public	0.226	0.218	0.9194
		Client's R	0.119	0.243	1.0000

PSC32	Public	Client's R	-0.488	0.277	0.2537
		Contractor	-0.717	0.284	0.0439
	Client's R	Public	0.488	0.277	0.2537
		Contractor	-0.229	0.316	1.0000
	Contractor	Public	0.717	0.284	0.0439
		Client's R	0.229	0.316	1.0000

* *The mean difference is significant at the 0.017 level.*

Appendix K1: Questionnaire (3) for Multivariate Discriminant Analysis

Component 1:
Sample classification (about your organisation)

1. Organisation types (please circle):

Public clients	Client's R clients / clients' representatives.
1	2

2. Regional classification (please circle):

England	Northern Ireland	Wales	Scotland
1	2	3	4

3. Annual turnover / budget (please circle):

Below £5 million	£5-50M	Above £50M
1	2	3

Component 2:
The following are the variables for measuring of contractors' performance. Please give one of your previously completed projects for answering of this component. For clarity and to avoid ambiguity 'fair' or 'moderate' performance are grouped into 'good' pool.

4. Type of project (please circle):

Building (e.g. repair/maintenance/new construction)	Civil (e.g. repair/maintenance/new construction)
1	2

5. Time (in month, give number only e.g. if ***20 months*** than ***20***):

Actual Completion time:	Estimated contract duration in tender:

6. Cost (in £ currency, give number only, e.g. if ***£ 1 million*** than ***1,000,000***):

Final cost	Tender price

7. Quality (please circle once for this question):

Poor quality compared with the specifications	1
Slightly poorer than average compared with the specifications.	2
Meeting the requirements of the specifications	3
Slightly better than average compared with the specifications.	4
Good quality compared with the specifications.	5

8. Contractor overall performance of that project (please circle):

Good	Poor
1	2

Component 3:
The following are contractors' attributes (PSC) that you considered for evaluation of the particular contractor (who completed the project) during tender evaluation. A *three point* and *five points* Likert scale are used: e.g. 1 to 3; 1=poor 2=average; and 3=very important / satisfy. Or, 1 to 5; 1=poor; 3=average; and 5=very good / satisfy. **However, if you do not agree or never used the criteria mentioned in this component during tender evaluation please circles '1'** (i.e. poor / no significant impact). Information for this component should stick to the project as cited in Component-2.

A *Staffs quality and experience (please circle):*

9. Staff training programme.	1	2	3	4	5
10. Performance of the project manager(s):	1	2	3	4	5

11. Staff quality (please specify in number, or an approximate number):

No. of professional qualified staff*	Total nos. of staffs:	Ratio (leave it blank):

**Member of professional bodies e.g. RIBA, ICE, RICS, CIOB, etc.*

12. Project manager(s) experiences:

No. of years	

B *Plant and equipment resources (please circle):*

13. Condition and procedure of equipment:	1	2	3	4	5
14. Suitability of the plant and equipment:	1	2	3	4	5

C Contractor site management / execution capability (please circle):

15. Type of control and monitoring procedures (proposed):	1	2	3	4	5
16. Cost control and construction progress reports systems (proposed)	1	2	3	4	5
17. Ability to deal with unanticipated problem (i.e. risk Management)	1	2	3	4	5
18. Provision trained / skilled staff / foremen for that particular project:	1	2	3	4	5
19. Contractor's IT knowledge e.g. project management software / electronic document management systems	1	2	3	4	5

D Health and safety (please circle):

20. Proposed health and safety programmes:	1	2	3
21. Health & Safety records on previous projects:	1	2	3

E Past performance in that project (please circle one):

22. Time	1	2	3
23. Cost	1	2	3
24. Quality	1	2	3

F Contractor capacity:

25. Current workload (please specify in number, for £ currency only, e.g. if **£1 million** than **1,000,000**):

Total contract sum in hand (approximately)	total nos. of staffs:	Ratio (leave it blank):

G Contractor reputation / image (please circle):

26. Contractor reputation / image.	1	2	3	4	5

27. Origin of the company (please circle):

Local	National	International
1	2	3

28. Number of years in the business (please specify in number, e.g. if **25 years** then **25**):

Nos. of years	

29. Listed on the stock market (please circle):

Yes	No
1	2

H Contractor's proposals (please circle):

30. Construction schedules and procedures:	1	2	3	4	5
31. Construction methods / statements:	1	2	3	4	5
32. Site organisation; work rules / procedures and policies.	1	2	3	4	5
33. Proposed site management and productivity improvement procedures.	1	2	3	4	5

34. Tender price(please circle):

Lowest	Average	Above average
1	2	3

I Other criteria that you might considered (give influence to your selection decision) when you evaluating the contractor for the particular project as cited in Component-2, e.g. 1= no impact, 3=moderate impact; and 5= significant impact (please circle):

35. Contractor familiarity with weather conditions:	1	2	3	4	5
36. Contractor familiarity with local labour:	1	2	3	4	5
37. Contractor familiarity local supplier:	1	2	3	4	5
38. Contractor familiarity with geographic area:	1	2	3	4	5
39. Contractor relationship with local authority:	1	2	3	4	5
40. Home office location to job site location	1	2	3	4	5
41. Communication and transport method from office to job site	1	2	3	4	5
42. Experience with specific type of facility.	1	2	3	4	5

44. Please tick if you would like to receive a summary of these research conclusion: ( )

45. If you would to receive a copy of research summary please leave your name, address, contact number (if you like to have a discussion), e-mail, etc.

Name:.................................. Post:.......................... Department:........................

Company name / Address:...

....

Tel.:..................................... Fax:.............................. E-mail:..............................

Appendix L:

Research Summary in *Construction News*

HAMMERING ALONG: Morrison Developments and joint venture partner Ironbridge Estates signed up nine new retailers last week for their £11 million Bligh's Meadow shopping centre in Sevenoaks, Kent. Morrison Construction is building the city-centre development, which will contain 24 retail units when construction is completed by the end of October.

ster is dismissed following her exposure of collapsed subbie

ıx construction ister gets sack

Lease. This has forced a probe into the scheme by the public accounts committee, but Mrs Cannell has now been relieved of her post at the Department of Trade & Industry.

She said: "This government has been extremely good at defending Bovis and the design team, but who is defending the public now?"

Isle of Man chief minister Donald Gelling said: "It has been claimed Mrs Cannell's removal was because of her questioning of government policy, her opposition to the construction of the new hospital and her determination to speak freely on government matters. Nothing could be further from the truth.

"In relation to the new hospital, her statements were often erroneous and intemperate, undermining the public credibility of the project. It was this unwillingness to work with the Department of Health and Social Security in discussing her concerns and her continuous undermining of the hospital which left the Council of Ministers with no realistic choice but to sever Mrs Cannell's links with the DTI."

Cannell: relieved of post

Mrs Cannell denies issuing incorrect statements. She said: "The only incorrect information I generated was when I asked [health minister] Clare Christian about the overpayment. I thought it was only £350,000 when it turned out to be £380,000."

The Public Accounts Committee inquiry into the hospital starts on May 11 and Bovis project manager Keith Redhead will appear, along with other representatives of the design team.

David Crowe and Mike Mottram, directors of failed subbie Crowe EPH, have also been hauled before the committee, as have Ms Christian and Keith Tomlinson, chief executive of the Department of Health and Social Security.

University bidding to make mark

ACADEMICS at the University of Wolverhampton are appealing to the construction industry to provide information for a new research project aimed at benchmarking contractors' strengths and weaknesses.

The study will analyse contractors' past performances, financial stability and health and safety records to try and predict future performances.

Researcher Andy Wong said: "We would like to hear from contractors and clients."

The research is intended to help industry clients choose the right contractor for the job. The long-term aim is to improve value for money and create greater cost efficiencies during the tender process.

Potential benefits for contractors include not being awarded contracts they are subsequently incapable of fulfilling and an increase in fair competition at the tender stage.

Interested firms can e-mail Andy Wong at the University of Wolverhampton at: e9671210@wlv.ac.uk

Carillion calls

Accountant convicted of

Appendix M1:

Correspondence from Public Client

CROYDON COUNCIL

Please ask for/reply to Gary Seed
Tel/Typetalk 020 8686 4433 Ext. 2720
Direct Dial 020 8407 1318
Fax 020 8760 5571
Minicom 020 8760 5797
E-mail gary_seed@croydon.gov.uk

Mr C H Wong
BERU, SEBE
Wulfruna Street
Wolverhampton
West Midlands
WV1 1SB

www.croydon.gov.uk

Your Ref:
Our Ref: CS/PD/GS
Date: 28 June 2000

Dear Andy

Contractor Evaluation: Lowest Price or Quality

Further to your letter 13 June 2000. Please find attached the completed questionnaire using an example of a contract completed in a manner that could be described as "poor performance" on the part of the contractor.

There are a few questions that I have left unanswered in component 3.

Questions 11 and 12, have been left blank as they were not an evaluation criteria however, for information the company concerned has 1 "professional" out of a total of 22 staff and the project manager for this particular project has 16 years experience.

Question 25 was not an evaluation criteria however, we do as an authority limit the total amount of contract award to approximately 30% of annual turnover. This of course ignores all contract values awarded to companies by others.

Question 28 also has no bearing in the evaluation of companies other than for the provision of audited accounts for financial appraisals. We would expect to receive at least 2 years to enable companies to be considered for contract award above 75K.

For your information, the works example used, relates to the refurbishment of a lift installation in a small block of Council flats. The poor performance was assessed against:

- Time
- Attitudes to Claims for Delay and Disruption
- Agreement of Final Account

Other areas that can be used in monitoring the performance of a contractor are:

- Adequacy of Labour Strength.
- Head Office Organisation.
- Site Organisation.
- Agreement of Valuations.
- Compliance with Contract Instructions.

Customer Care.

We inform all contractors of "poor performance" issues and depending upon their response, reserve the right to use the monitoring information for future tender selection.

I hope this all makes sense.

Yours Sincerely

Gerry Seed

G Seed

Miles Smith - Director of Corporate Services

Liz Calcutt - Head of Procurement

Corporate Services Department, Taberner House, Park Lane, Croydon, CR9 3JS

Appendix M2:

Correspondence from Client's Representative

Our Ref: MC/EC

vector

Monday, 03 July 2000

C.H. Wong
School of Engineering and the Built Environment
University of Wolverhampton
Wulfruna Street
Wolverhampton
WV1 1SB

Dear Sirs

RE: CONTRACTOR EVALUATION: LOWEST PRICE OR QUALITY

Apologies for the delay in responding, but please find enclosed the completed questionnaire.

I was a little confused with the format and I have completed the questionnaire, as best I can. However, you might find the following of interest.

The "Client base" is clearly making the statement that they require a higher degree of certainty in terms of time, quality and cost and that they are prepared to accept a higher tender for risk aversion. The selection criteria therefore covers the following:

1. Quality of deliverable.
2. On time.
3. On or under budget.
4. Understanding key discriminator.
5. Management of risk.

I trust this is of use to you.

Yours sincerely

Michael G. Crooks
Senior Project Manager
For Vector Management Ltd

Appendix N:

Correspondence from Construction Industry

Ian Campbell
Manager - Building Design Agency
BUILDING SERVICES

PO Box 108, Harvey Combe
Killingworth
Newcastle upon Tyne
NE12 6WQ

Direct Line (0191) 219 2060
Switchboard (0191) 219 2054
Fax (0191) 219 2055

NORTH TYNESIDE COUNCIL

Our Ref: BDA/IDC/SHL

Your Ref: 13

Date: 4 May 1999

This matter is being dealt with by: Mr I D Campbell

Mr C H Wong (Andy) Directorate Researcher
MA 170 Built Environment Research Unit
School of Engineering and the Built Environment
Wulfruna Street
WOLVERHAMPTON
West Midlands
WV1 1SB

Dear Mr Wong

Contractor Pre-qualification

Thank you for your kind letter and synopsis of your preliminary study which I received on 16 April 1999.

I do appreciate the heavy workload you are undertaking so I will not ask that you forward me more detailed information. However, I am interested in your research and I will be pleased to assist you in future research.

Yours sincerely

Ian Campbell

Manager - Building Design Agency

05idc.doc/1

Return-path: <helen.walker@jrknowles.com>
Envelope-to: C.H.Wong@wlv.ac.uk
From: Helen Walker <helen.walker@jrknowles.com>
To: "'C.H.Wong@wlv.ac.uk'" <C.H.Wong@wlv.ac.uk>
Subject: FW: Research
Date: Thu, 4 May 2000 14:00:13 +0100

-----Original Message-----
From: Helen Walker
Sent: Thursday, May 04, 2000 01:53
To: 'andywong@wlv.ac.uk'
Subject: Research

Dear Mr Wong

I read with interest the article in Construction News May 4th, regarding your proposed research. James R Knowles are an established firm of Construction Contract Consultants.

We offer a wide variety of services, including:

Partnering
Procurement
Best Value
PFI

I do not know if we would be able to help in your research, however I am very keen to hear more about the project.

If you would like to send me some information or contact me, please do so.

Regards

Helen Walker
Research & Sales Development Manager

James R Knowles
Langdale House
Gadbrook Business Centre
Rudheath
Northwich
Cheshire
CW9 7UL